A LABORATORY MANUAL FOR FIRST COURSE IN BOTANY

EVANS

654

IT IS AN EXCELLENT SPOT FOR STUDY BY OUTDOOR CLASSES (THOMPSON)

A LABORATORY MANUAL

FOR

FIRST COURSE IN BOTANY

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PREFACE

The exercises contained within this manual are designed to accompany Pool and Evans's textbook, "First Course in Botany." It will therefore be found to present the laboratory work in the same sequence as the work is given in that text.

The great value of a laboratory manual written specifically to accompany a given text is that it may be made to parallel and supplement the latter in a way that would not be possible otherwise. Any ideas that the text contains that are considered important are likely to be stressed in the manual as they should be. If the student is to get the most out of a course in botany, it will be because those points which seem difficult in the text are made clear with a few simple laboratory exercises.

This manual is not designed to be the last word in what the teacher should do in a course in botany. It is offered more as a suggested outline of work which may be followed. Any other botanist might write such a manual and present an entirely different line of experiments all as good as those here given. If these are to be of value it is largely because they are a corollary to the text we have written. It is hoped that the work here presented will not be slavishly followed by any teacher, but that it will be enlarged upon as the needs of the students may require. Many exercises may be omitted entirely. Others may be performed and similar additional work assigned. Often the teacher will find it helpful if outside readings are assigned for reports either written or oral. Written reports will be found to have two advantages over oral recitations. One is that it requires more

concentration on the part of the student to read the references and then write a report; and the other is that it gives the teacher an opportunity to check the work more closely, for very often a student may read without understanding. The student may be required to report orally after he has handed in the written composition.

This manual has been designed to require a minimum of microscopic work. There are several reasons why microscopic work among elementary students may not be successful. Again, many schools are not fully equipped to carry on this type of work. It will be found, therefore, that many of the experiments require little more equipment than a hand lens. It will also be noted that morphology is not made a prominent feature of this manual, although always mentioned where occasion seems to demand. It has been our experience that young students soon tire of structural studies alone. They are more likely to take a keen interest in something which holds a secret to uncover. Much simple physiology has therefore been woven into the outlines. In many cases this will need to be altered. The experienced teacher will wish to replace many of the exercises here outlined by his own. To the young teacher this manual will be a guide until such time as he becomes equipped with ideas and exercises which he may devise for himself. In fact, we are thoroughly convinced that it is not what is given so much as how it is given that makes any course worth while. The personality and leadership of the teacher are the important things in teaching young students.

It is our hope that such a course as this may be early introduced into the curriculum. The study of botany offers an admirable approach to the study of animal biology and human physiology. It is of great value as an introductory course because plants are so universal and lend themselves so readily to experimentation. It is not impossible to do the same things with animals; but all the principles of animal

and human biology may be discovered in the study of plants. Respiration, transpiration, digestion, and numerous other studies are readily demonstrated by them. The destruction of plants and the study of reproduction as shown by them call forth less of comment than the same study in animals; nevertheless every principle to be found in animal study is easily illustrated by plants. For this reason alone the study of plants early in the high-school course not only prepares the student scientifically, but also shapes him mentally for a better attitude in the study of animal biology and human physiology. The fact that plants are so fundamental in the initiating of food manufacture would in itself be a sufficient reason, if there were no other, for the early introduction of the study to young students. With a knowledge of this very important fact in mind the student is readily guided through the maze of complicated biologic principles which comes with a study of animals that must maintain themselves at the expense of other food supplies.

Too often in our teaching we are inclined to make the spectacular maintain the interest of the student instead of maintaining it through a real enthusiasm for work and then making the spectacular the fitting culmination of a series of experiments. We believe that a practical turn gives a manual of this type some value that cannot be derived from a book which does not have it. We have therefore tried to do this by including such discussion as may lead the student into ways of thinking for himself. If he does this, he will often be righted on many misconceived notions obtained through stories from his friends, or even at home. Most people have an entirely erroneous notion of the true situation concerning bacteria. To many a bacterium is a terrible thing which will produce some fatal malady. As a matter of fact we consume numberless quantities of bacteria every day, many of which are essential to our well-being. We have stated that only a few bacteria are really

harmful, the great preponderance of them being highly useful or of no significance.

The work here included is a series of laboratory exercises more or less the property of botanists at large. No claim is offered as to originality in most cases. Much of it has been used in the author's classes from time to time. In all cases with a little precaution it will be found to be easily handled by any students, regardless of their previous scientific training.

The author wishes to acknowledge his indebtedness to a number of sources, especially to Dr. Otis W. Caldwell for several illustrations. The illustrations have been credited in each case. He wishes also to acknowledge his indebtedness to Mr. Schuyler Matthews and Mr. H. C. Britzmann for a number of original drawings.

ARTHUR T. EVANS

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LABORATORY MANUAL FOR "FIRST COURSE IN BOTANY"

INTRODUCTION

LABORATORY NOTEBOOKS IN BOTANY

The laboratory notebook selected should be one that can be kept accurately and neatly.

Drawing paper. For good work it is necessary that a good grade of heavy, smooth drawing paper be used. Thin sheets, ruled sheets, and rough, cheap types will prove unsatisfactory. So little drawing paper is required in a year's work that the expense of a good grade is but a very slight increase over cheaper grades. The sheets are to be regular notebook size, $8\frac{1}{2} \times 11$ inches. They should be punched with two holes for binding.

Drawing equipment. Each student will need a medium-hard drawing pencil. The 4H grade is the most satisfactory. He should also have a good eraser and a good ruler (a six-inch celluloid ruler is satisfactory).

Drawings. Drawing should be made on only one side of the paper. An effort should be made to place the drawings logically and symmetrically on the page. Haphazard placing of drawings is not the mark of the true scientist.

All drawings are to be made very lightly at first. Corrections and erasures can then be made without marring the page. When the drawing is correct, it can be traced in more heavily. Care, accuracy, and neatness are lessons that every student should learn from laboratory work in botany.

It is generally not advisable to shade drawings. Clear-cut, uniform lines are very desirable. Students should never be allowed to make interrupted or crooked lines when they should be otherwise. It is a habit hard to break when once formed. In drawing cells it is never permissible to continue cell-wall lines across the point where they should stop, so that they end in the cell cavity of the next cell. This is not the condition in specimens, and such drawings should not be permitted in a well-conducted laboratory.

Leave a margin at the left-hand side of the page. In general it is desirable to place the drawings along the margin on the left-hand side, with all labeling to the right. All labeling should be direct and not by a system of key letters which refer to legends at the bottom of the page or elsewhere. It is well to have all leader lines to labels run parallel to the top of the page after leaving the drawing. At any rate the lines should never cross, and the labeling should be horizontal on the page.

Drawings are much more attractive when all labels are printed (Figs. 1 and 2). Many students will have to learn how to print, but this is easy enough. In printing make the letters as they appear on this page. Printed labels are always used for figures in books, and it is well for students to follow the same plan.

Headings and titles. At the top of each page a proper heading should be printed, as: Study of Flowers; Study of Leaves; Study of Osmosis; etc. All letters in these titles should be capitalized. Below each drawing there should be a legend telling very concisely what it is, as: A Nasturtium; An Elm Leaf; Apparatus for Osmosis Experiment; etc. The main words should be capitalized. Place your name as your signature, together with the date, in the lower right-hand corner of each sheet before you commence to draw. It definitely identifies it as your work. This should be required at all times.

At the end of each laboratory period drawings should be left for correction. They will be returned at the beginning of the next period, with correction marks. Each student will make the corrections and erase marks which the instructor has made. Always leave the drawings loose in a manila cover. The same cover may be used from day to day. Distinguish your work with your name, your division, and the classroom in which you meet, thus:

DONALD SHEPHERD
SECTION I, 8–10 A.M.
ROOM 302

This should be placed in the upper right-hand corner of the front cover. You may print "Botany Notebook" across the middle of the front page.

Questions and answers. The questions and answers which are to be included in the notebook should be written on ruled paper the same size as the drawing paper and be placed just before the drawings. You may write on both sides of the paper in doing the composition work unless for some reason the teacher desires that one side be left blank. Do not forget to leave a margin of one inch along the left-hand side of the page. The composition work should all be in ink.

Paragraph each new subject and underline the paragraph titles, as: A Study of Leaves.

To be of value composition work must be clear and concise. If you do not write clearly, then you should practice writing. This work will afford you a good opportunity. In writing a report after doing outside reading do not copy the book. Do not try to write too much. Get the thought of a paragraph and then put it into a clear-cut sentence.

The study of botany is very interesting indeed, and you can get a great deal out of it if you will. You will

appreciate nature and the plants that grow about you more and more if you will study with a real endeavor to learn.

The following is a brief summary with which the student should familiarize himself:

1. For drawings use heavy linen ledger paper $8\frac{1}{2} \times 11$ inches, provided with punch holes for fastening into a manila cover. Always have on hand a cover into which drawings and notes may be bound. Use ruled paper of the same size for composition work. Always insert it just before the drawings on the same subject.

2. The drawing pencil should be HHHH or else No. 4H. Keep the pencil sharp with the pencil-sharpener and have the lead pointed with sandpaper, a piece of which should be tacked up in every laboratory. All lines in the drawings are to be sharp and clear; all unintentional lines must be erased.

3. Have a good red-rubber eraser. Art-gum erasers are useful to clean up pages. Trim the eraser to a fine edge so that lines may easily be removed without disturbing other parts of the drawing.

4. Always leave an inch margin at the top and left side of the page. Print a proper general heading at the top of the page before beginning to draw, and also put your own name (in ink) in the lower right-hand corner of the page. Have the name of the object below each drawing. Make the printing of reasonable size; not too large. The teacher will assume no responsibility for drawings without names. Any drawings lost must be done over. There is no appeal from this, so be careful.

5. Drawings are to be spaced without crowding and are to be in proper order on each page, and the pages are to be in order when they are fastened into a manila cover for final correction. No other material is to be included in the cover other than the required drawings and composition work. The drawings are to be left for correction each day.

6. Labels are to be printed, not written. The letters should be about the size of ordinary print, not smaller. Answers to questions may be written. Be sure to form your printed letters correctly. Look in any book to see proper form of letters. Be particularly careful of such letters as b, d, f, l, m, n, r.

7. All labeling is to be done directly, not by means of reference letters or numbers. Use a ruled dotted line to extend from the

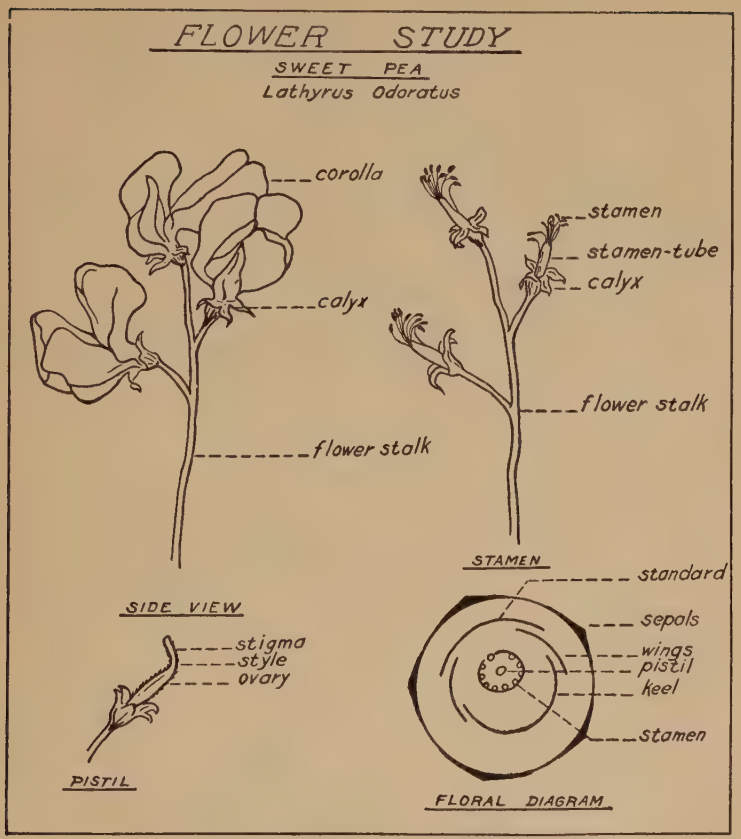

FIG. 1. Typical page from a student notebook

This work was done in class. Note the well-balanced arrangement and the neatness of style. (Drawn by H. C. Britzmann)

printed word to the particular part of the drawing to which it refers. Every printed or written word is to be horizontal on the page. Study Figs. 1 and 2 as a guide.

8. The printed directions sometimes describe more work than you will have time to do. Do what is called for by the instructor. If you find time for additional work, some can always be furnished. Students must in no case leave the laboratory before the closing

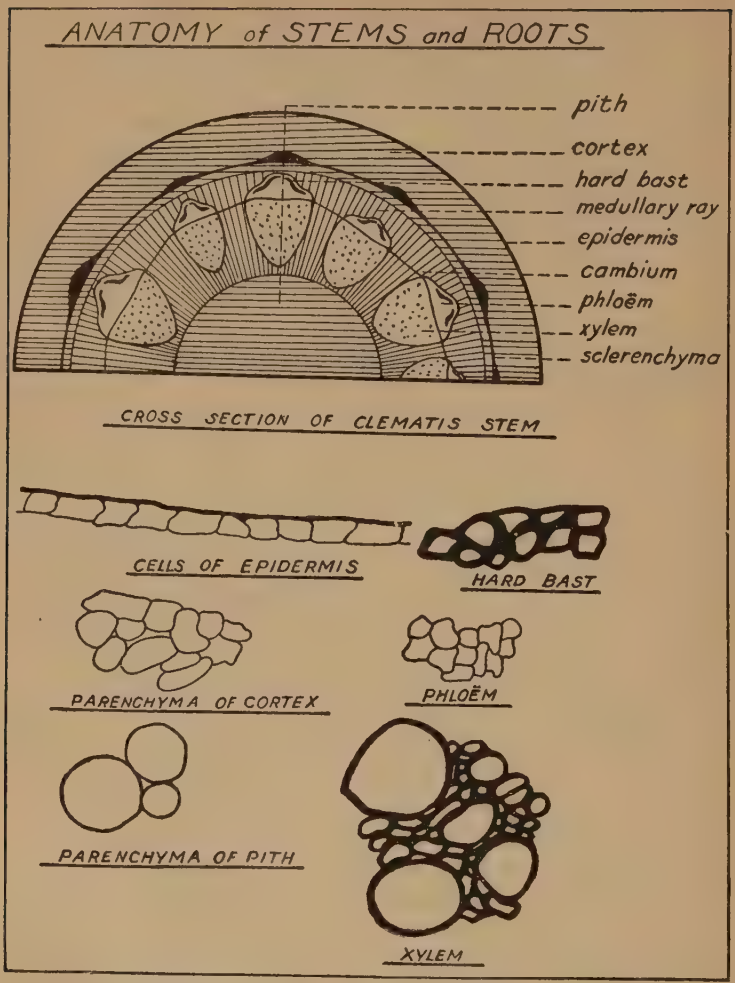

FIG. 2. Another typical page from a student notebook

Drawn by H. C. Britzmann

bell rings. The last few minutes, when there is not time to undertake a new piece of work, may be profitably used in going over drawings, improving lettering, or in studying your work.

9. When books are to be handed in for final inspection be sure to go over them carefully for spelling, lettering, and other matters. This is important and deduction will be made for misspelled words if the student persistently fails to correct the fault. Clean up the pages with an eraser. Have the cover clean. Have the sheets fastened in so loosely that they can be readily turned over without tearing at the punch holes.

10. Looking up drawings in the textbook is absolutely forbidden unless you are given permission. An open text will be considered evidence that you are doing this. Neither will borrowing drawings from others be allowed. Your work and yours alone is wanted.

11. Since a dictionary is available, there will be no excuse for misspelled and mispronounced words. Learn to use it. Students should learn to speak, pronounce, and spell correctly.

12. Students are not to move about the room to visit with other students.

LABORATORY EQUIPMENT

In secondary schools very often the requirements for space make the arrangement of a botany laboratory impossible. Other laboratories, especially in such allied subjects as zoölogy, biology, and general science, must be held in the same room. This is not altogether without merit. Much of the equipment, such as glassware, tubing, and even plants, may be used in common. Permanent equipment, such as desks and chairs, are readily interchangeable.

No laboratory can be well conducted without a minimum of laboratory equipment. Flat-topped tables of nearly any type will do. It is desirable that these be wide enough to accommodate students seated along each side. Where a laboratory is being especially equipped for botany and allied sciences it is well to consider securing tables wide at one end and narrow at the other, which may be placed with the wide end against the wall in front of the window. If the end away from the windows is narrower, a student seated there does not have his light cut off by other heads. Drawer space is not always essential for students. Where every-

thing is furnished, as is the case in many schools today, the teacher can more readily keep such materials for distribution at the beginning of each period. If drawer space seems necessary, it may be provided in the tables or as separate lockers. Since such space when not in use is likely to become a catchall for various materials, it should be eliminated if not needed. Closet room or special cases are necessary for the storage of equipment.

To be of the greatest service every laboratory must be provided with gas and water as well as electricity. A single large sink and a few gas jets along a single table will usually suffice. In some well-lighted space, preferably before a window, there should be at least one aquarium. A few battery jars form convenient culture dishes for single species of algæ and the like. An aquarium should be filled with soft water, and such plants as elodea, duckweed, and various other water plants should be kept growing in it. Algæ are always sure to develop in such places. A pail of water from any convenient stream or lake makes an ideal starter for such an aquarium. An aquarium is not only a constant source of supply for the laboratory work but very often can be used for illustrative purposes. A glassed-in case (often called a Wardian case) is very useful in keeping plants for study in the laboratory. It can be kept moist, which is not always true of the laboratory. It is almost essential where no greenhouse facilities are available.

Most other articles of permanent equipment, exclusive of apparatus, can be made with the exercising of a little ingenuity.

Where new tables are provided for a laboratory it is always well to have the tops black. There is a minimum of reflection from such tops, and light-colored objects are more easily seen upon such a background. Then, too, they are easily kept clean and add to the general neat appearance of the laboratory.

Table tops may be blackened in one of two ways: they may be painted with acid-fast paint, which may be purchased from any reliable dealer, or they may be treated by a homemade compound, the formula for which is given below. The latter method has been found very satisfactory, cheap, and convenient. It is readily applied and can be renewed from time to time, since much wear removes some of it. Both treatments render the tables acid-proof and give them a jet-black color. The second treatment is preferred, as paint is likely to become rough and hard to write upon. The formula for the solutions mentioned and the method of applying in case the second treatment is desired is as follows:

SOLUTION I

Copper sulphate	125 grams
Potassium chlorate	125 grams
Water	to make 1 liter

SOLUTION II

Anilin oil	60 grams
Hydrochloric acid	90 grams
Water	to make 1 liter

Solution I should be applied to the clean table top. Follow this immediately with Solution II several times until the color is very dark green. Allow each application of Solution II to dry. When the desired tone is reached, allow table top to dry and then scour with soap and hot water. Apply linseed oil and rub in well. The top will then be jet-black. To clean such a table top it is only necessary to rub with an oiled rag. Such a top will not be marred by anything which may be spilled on it.

APPARATUS AND EQUIPMENT

The course outlined in this manual is designed to make it possible for any school, large or small, to provide the equipment necessary. There are no materials required for the

work which are not easily obtained in any community. There is a minimum of material that will need to be purchased.

The plants listed to be used have been selected only after deliberation and with a view to their distribution and accessibility in all places where this manual may be used.

The apparatus required is simple and inexpensive. If the following articles are on hand, all the experiments may be performed. Where other apparatus is required, it can be made in the laboratory at very little expenditure of time and money. For much of the equipment listed other materials may be substituted. If a new laboratory is being started, it is well to have in mind such a list, which is sufficient for twenty-five students.

1 or more compound microscopes (desirable)
24 tripod magnifiers
1 Harvard trip balance or other convenient balance
6 feet of rubber tubing for Bunsen burners
3 Bunsen burners
1 gross plain white slides 1 × 3 in.
1 ounce No. 2 cover glasses
6 alcohol lamps
12 scalpels
2 dozen forceps
½ gross dissecting needles
½ gross 6-in. test tubes
1 dozen hard-glass test tubes
4 thermometers, F. and C. scale
25 feet of glass tubing, 5-mm. internal diameter
12 feet of rubber tubing, 5-mm. internal diameter
12 thistle tubes
12 250-cc. beakers
12 500-cc. beakers
6 1000-cc. beakers
3 bell jars 2 ft. high
4 bell jars 8 in. high and 10 in. in diameter
6 battery jars
1 dozen Mason fruit jars

1 1000-cc. cylindrical graduate
6 100-cc. cylindrical graduate
1 box slide labels
50 8-oz. wide-mouthed bottles
50 4-oz. wide-mouthed bottles
100 vials 3 in. high and 1 in. in diameter
1 gross assorted corks
1 dozen two-holed rubber stoppers
1 dozen one-holed rubber stoppers
1 dozen 500-cc. flasks
1 dozen 1000-cc. flasks

All the equipment here listed would cost but little above $100, when microscopes are omitted. Most of it would be used over and over with a little care. In many cases substitutions could be made and a number of articles here listed could be eliminated. Such chemicals as are necessary are readily obtainable from any supply house. Many may be procured at a drug store.

REFERENCE BOOKS

The following list of reference books is not designed to be all-inclusive, but to give a few good books of value in the preparation of outside reading. The list is short, and an effort should be made to make them all available. Numerous others are worth while and will in many cases be available to the student. No course can be well taught which does not supply the student with accurate information through good reference books.

BLAKESLEE, A. F., and JARVIS, C. D. Trees in Winter. The Macmillan Company.

The Book of Popular Science. (15 vols.) The Grolier Society, New York.

This series of books contains voluminous references to the world of plants. It is written simply and will be found a great aid to supplementary reading. It should be made available in every high school.

CLEMENTS, F. E., and CLEMENTS, E. S. Rocky Mountain Flowers. The H. W. Wilson Company.

Compton's Pictured Encyclopedia. (10 vols.) F. E. Compton & Company.

A splendid array of facts in simple, direct fashion. This work will be found of inestimable value to the young. It should be available in every school library. It will be found valuable in many other subjects aside from botany.

CONN, H. W. Bacteria, Yeasts, and Molds in the Home. Ginn and Company.

DANA, Mrs. WILLIAM STARR. How to Know the Wild Flowers. Charles Scribner's Sons.

FRANCIS, MARY EVANS. The Book of Grasses. Doubleday, Page & Company.

GEORGIA, ADA E. A Manual of Weeds. The Macmillan Company.

HOUGH, R. B. Handbook of the Trees of the Northern States and Canada. Published by the author, Lowville, New York.

MCILVAINE, MACADAM. One Thousand American Fungi. The Bobbs-Merrill Company.

MONTGOMERY, E. G. The Corn Crops. The Macmillan Company.

PAMMEL, L. H. Weeds of the Farm and Garden. Orange Judd Publishing Company, Inc.

PETERSON, MAUDE G. How to Know Wild Fruits. The Macmillan Company.

PIPER, C. V. Forage Plants and their Culture. The Macmillan Company.

ROGERS, JULIA. The Tree Book. Doubleday, Page & Company.

SARGENT, C. S. Manual of the Trees of North America. Houghton Mifflin Company.

STUART, WILLIAM. The Potato. J. B. Lippincott Company.

WALTER, H. E. Genetics. The Macmillan Company.

Bulletins on nearly any subject relative to plant life may be obtained free from the United States Department of Agriculture and from your state experiment station. The Yearbook of the United States Department of Agriculture is also available. Write for a list of such bulletins.

GENERAL SCIENCE — THINGS NOT ALTOGETHER ABOUT PLANTS

Exercise 1. A Study of a Compound

Carbon dioxide is one of the substances used very abundantly by the plant. It is a compound: a by-product of our breathing, of all burning, of decay, and of decomposition. It is present in the air in a ratio of 3 parts in 10,000.

Materials needed. Several wide-mouthed bottles; limewater; pine splinters; a small dish.

1. Breathe gently into a large-mouthed bottle for several minutes. Since we breathe carbon dioxide out as we exhale, and since it is heavier than air, the jar will gradually fill with it. Lower a burning splinter into the jar. Explain the results.

a. Will a splinter burn in an atmosphere of carbon dioxide?
b. What happens when a burning splinter is thrust into an atmosphere of carbon dioxide?

2. Demonstrate that carbon dioxide is present in such a jar and is heavier than air by pouring it slowly, as you would water, out of the bottle upon a burning splinter. Explain any results you see. (Unless carefully done, no results will be obtained.)

a. Is carbon dioxide a solid, a liquid, or a gas?

3. Prepare some limewater by placing a piece of calcium oxide as big as a baseball in a bottle and then covering it with water. Shake well and allow it to stand for some time. (It will be more convenient if the teacher prepares the limewater several days before. The students may also prepare it for practice. After using any of the solution of limewater,

refill the bottle with water, and a supply will always be available. It keeps indefinitely.) Filter off the solution. Pour about two ounces of this solution into a bottle in which you have just breathed. Shake well. The presence of carbon dioxide is indicated by a white precipitate.

a. Was carbon dioxide present?
b. Where did it come from?
c. Is it heavier than air?
d. What happened to the air in the bottle when carbon dioxide was breathed into the bottle?
e. What happens to air in a bottle when water is poured into the bottle?
f. What must we inhale?
g. Blow through a glass tube into a little limewater. Explain the results.

4. Lower a lighted splinter into a bottle of air and hold it until the blaze is extinguished. Cover quickly with a glass plate after removing the splinter. Test for carbon dioxide with limewater. Record your results.

a. Do you think any free oxygen remained in the jar? Why?
b. Does carbon dioxide result from combustion?
c. How would you remove carbon dioxide from a vessel of air?

5. Expose some limewater in an open dish for from one to two hours or, better still, overnight.

a. Explain what happens.
b. From this experiment what do you conclude concerning the presence of carbon dioxide in the air?

6. Why is carbon dioxide more abundant close to the earth than it is higher in the air?

Write a paragraph in your own words stating what you have learned concerning carbon dioxide. Read about carbon dioxide in one of the encyclopedias given in your reference list.

Exercise 2. A Study of Carbon, One of the Elements

Chapter I of Pool and Evans's "First Course in Botany" text gives a rather full discussion of *elements*. It will be worth while to learn some of these things directly through experiments.

Materials needed. Several splinters of soft wood; a flame; paper.

1. Prepare some charcoal (if none is available) by burning a splinter until it is well charred on the end; then extinguish the flame.

   a. Tell what you have done.
   b. Is charcoal a solid, a liquid, or a gas?
   c. Write with the charcoal on a piece of paper. Is it hard or soft?
   d. What color is it?
   e. Of what substance is wood composed in part?

2. Hold the tip of the carbon in a hot flame.

   a. What happens?
   b. Does the carbon disappear?
   c. Does it change into a gas, a liquid, or a solid?
   d. Tell what element unites with it.
   e. Where does the oxygen come from? Would you say air contains oxygen? Read about air in some reference book.
   f. Where does the substance that is formed go?
   g. What, then, is one of the sources of the carbon dioxide in our atmosphere?

Exercise 3. A Study of Oxygen and Oxidation

If carbon will burn and unite with oxygen in the air, it will be worth while to note the effect when it is burned in pure oxygen. The student should proceed to prepare oxygen.

Materials needed. Potassium chlorate; black oxide of manganese; large test tube; stoppers; delivery tube; basin of water; support for test tube; flame.

Preparation of oxygen. Mix about a tablespoonful of the potassium chlorate with about one fourth its bulk of the black oxide of manganese in any convenient dry receptacle. When thoroughly mixed, place in a large test tube. Close the mouth of the test tube with a stopper through which passes the delivery tube (Fig. 3). Support the test tube by an iron support. The other end of the delivery tube must extend below the water in the basin. Heat the test tube and its contents gently with a flame until bubbles begin to rise from the tube through the water. Now fill a bottle with water and cover tightly with a small glass plate. Invert the bottle, placing the mouth under the water in the basin. Remove the glass plate and place the bottle over the end of the delivery tube. Gentle heating of the test tube will drive off oxygen, which will replace the water in the bottle. The first bottle should be discarded, since it will contain the air which was in the apparatus. The contents of the next bottle will be pure oxygen. When the bottle is full cover its mouth with a glass plate while still under water, then place it, tightly covered, on the table for use. Prepare four bottles of oxygen in this way. Write up the method of preparation. Draw the apparatus you have used.

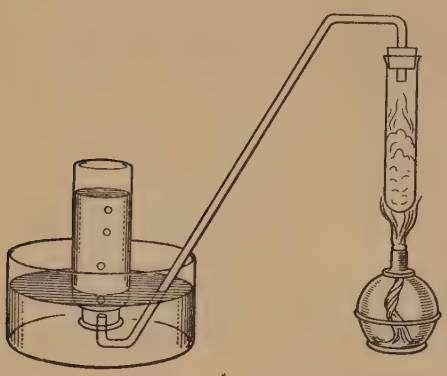

FIG. 3. Method of setting up apparatus to make oxygen

1. Examine a bottle of oxygen.

   a. What color is it?
   b. Is it a gas, a liquid, or a solid?

2. Secure a piece of charcoal and hold the tip in a flame until it glows. Lower the glowing tip into one of the bottles of oxygen and leave it until all reaction has ceased.

a. Explain what happened.
b. Why was the reaction so vigorous?
c. What can you say of oxygen in relation to combustion?
d. Test for carbon dioxide. Is it present?

3. Remove the cover from one bottle of oxygen and allow it to stand uncovered. Invert another bottle and then remove its cover. Be careful that the mouth of the second bottle is not sealed against the table. Allow the bottles to remain in this position for several minutes. Test each with a splinter for oxygen. Thrust the splinter into them without changing their positions.

a. Which bottle contains oxygen?
b. Is oxygen heavier or lighter than air?

4. When carbon and oxygen unite, as in the above, carbon dioxide is formed. Place some limewater in bottle number one and shake. If a precipitate is formed, carbon dioxide is present.

a. Is carbon dioxide present?
b. What happens when anything burns?
c. Is heat given off?
d. To what is this energy due?
e. Is oxidation a common process? Give some examples.

5. The union of carbon and oxygen, two elements, forms carbon dioxide, a compound.

a. What is necessary to bring about this union?
b. What becomes of the carbon dioxide?

6. The union of oxygen with any substance in this way is called *oxidation.* Write a paragraph in your own words about oxidation. Read about oxidation in some reference book.

Exercise 4. A Study of Nitrogen

Nitrogen makes up about 78 per cent of the air. It is an inactive gas. We breathe much of it without any effect.

1. Float a small lighted candle attached to a piece of cardboard on the surface of some limewater. Now invert a bottle over the candle until the mouth of the bottle is below the surface of the limewater. Keep in this position until the candle goes out.

a. Why does the candle go out?
b. What compound is formed while the candle is burning?
c. What element is used up?
d. Does the limewater within the neck of the bottle rise? Why?
e. Is a precipitate formed? To what is it due?
f. If the air in the bottle is composed largely of carbon dioxide, oxygen, and nitrogen, what is left in the bottle when the candle goes out?
g. What has become of the oxygen?
h. What has become of the carbon dioxide?

2. While the mouth of the bottle is still under water remove the candle and close the mouth of the bottle by slipping a glass plate over it. Be sure to retain the limewater which has entered the neck of the bottle. Holding the cover on the bottle tightly, shake thoroughly so that all carbon dioxide is removed.

a. What is left in the bottle?
b. Is the nitrogen a solid, a liquid, or a gas?
c. What is the color of nitrogen?

3. Thrust a burning splinter into the nitrogen.

a. Does the nitrogen burn?
b. Does the splinter continue to burn?
c. How does nitrogen differ from oxygen?
d. Of what value is nitrogen?
e. Why is there so much nitrogen in the air?

4. The amount of water in the bottle when the candle ceases to burn represents approximately the space formerly occupied by oxygen. Repeat the experiment to determine this, if necessary. Level the water inside and out.

a. What fractional part of the air in the bottle was oxygen?
b. What part is nitrogen?

5. Remove the cover from the bottle and determine whether nitrogen is heavier or lighter than air.

a. How can you do this?
b. What becomes of the nitrogen?

6. After reading some reference book, write a paragraph in your own words on the subject of nitrogen.

SOLUTIONS

A *solution* is formed when one substance dissolves in another. The substance that is dissolved is the *solute* and therefore it is *soluble.* The liquid is the *solvent.* Water is one of the best *solvents.* It will dissolve more substances than any other liquid. Some substances are very insoluble in many solvents.

In the formation of a solution the particles of the solute tend to become equally distributed throughout the solvent. It is in the presence of solutions that most life processes occur. Even though most plant and animal bodies seem to be solid, they are largely composed of water.

Exercise 5. A Study of Solvents and Solutes

Materials needed. Several glass tumblers; sugar; salt; iron filings; granulated carbon or chips of charcoal.

1. Fill four tumblers with water. Place in the first a teaspoonful of sugar, in the second a teaspoonful of salt, in the third a teaspoonful of iron filings which have been

washed, and in the fourth a teaspoonful of granulated carbon or chips of charcoal. Agitate for several minutes.

a. Which have formed solutions?
b. Why have not the others?
c. Where have the sugar and salt gone?
d. Are they equally distributed throughout the liquid? This can be proved by using a partition in the dish, placing the water on one side and the sugar on the other. Remove the partition carefully. Will the sugar solution mix through the pure water, that is, does all the water become sweetened?
e. Where have the iron filings and carbon remained?
f. Do they form solutions?
g. What conclusions can you draw as to the solubility of these four substances in water?

The passing of one substance through another, as sugar through water, is known as *diffusion.*

Exercise 6. A Study of Diffusion

It is stated in the text that although minute connections between cells directly through the cell walls have never been demonstrated, they are believed to exist. Water in one cell, then, would be connected with water in another cell by this minute thread of liquid. Through these threads salts may pass from one cell to another. To demonstrate that salts may pass through such columns, perform the following experiment:

Materials needed. Two 500-cc. beakers or battery jars; a siphon made from 5-mm. or larger glass tubing; water; bluing (such as is used to blue clothes).

1. Fill one beaker nearly full of water, and the other slightly less than half full. Now fill the siphon with water by placing it under the faucet and allowing water to flow into it. When full, close the ends of the siphon tightly and lower them thus closed into the beakers of water. (The

beaker which contains more water may be designated as beaker 1, and the other as beaker 2.)

a. What happens when the siphon is lowered into the beakers and the ends are uncovered?
b. In which direction does the water flow?

2. While the water is still flowing, pour a teaspoonful of bluing into beaker 2. The bluing should be put into the beaker with care so that it will remain near the top while the siphon opening is about half an inch from the bottom of each beaker. This can be adjusted with a support.

a. What happens when the water in the beakers reaches the same level?
b. Could there be any possible flow of water from beaker 2 to beaker 1?

3. Place the experiment aside in a quiet place where it may be observed occasionally.

a. Does the bluing diffuse throughout all the water in beaker 2?
b. How long does it take?
c. Did the flow of water from beaker 1 set up currents sufficient to mix it?
d. How do you know the flow of water through the siphon was from beaker 1 to beaker 2?

4. Observe the experiment every day for two weeks or more.

a. Does the bluing leave beaker 2?
b. If so, explain in detail how it can do this.
c. Will it ever reach beaker 1?
d. How long did it take?
e. Do you see any comparison in this connection between two beakers and the thread of water in plant cells?
f. Would the passage be faster between plant cells?
g. Explain why this is so. Read references on diffusion.
h. How do you explain the movement of the bluing from beaker 1 to beaker 2?

Exercise 7. A Study of Osmosis

The passing of solutions through plant and animal cell walls, or membranes, is known as *osmosis* and is one of the essential features of plant activities.

Materials needed. A thistle tube; brown molasses; a membrane; Fehling's solution. The membrane best suited is a piece of intestine or bladder which can be procured from any butcher. The membrane should be cleaned. It should be large enough to cover the mouth of the thistle tube. Such membranes are composed of cells. Fehling's solution may be purchased at a drug store.

1. Nearly fill the bulb of the thistle tube with molasses. This can be done by holding the tube upright and pouring the molasses directly into the bulb. Be careful to avoid getting molasses on the outside of the thistle tube. It will be necessary to close the lower end of the tube with the thumb or finger. Wash the membrane in water, dry as well as possible with a cloth, and tie it tightly over the mouth of the thistle tube. Invert the thistle tube and observe whether or not it leaks. If it leaks, it will be necessary to prepare the experiment again.

Lower the thistle tube, when satisfactorily prepared, into a vessel of water, bulb end down, and, with a pipette, drop water into the stem of the thistle tube until the level of the liquids inside and outside is the same. Connect a long piece of glass tubing with the upper end of the thistle tube and support it in an upright position. If the experiment is carefully prepared, the molasses will be completely separated from the water by the membrane.

2. Set up a control experiment exactly the same as in 1, except that water instead of molasses should be used in the thistle tube as well as in the vessel.

3. Allow the apparatus to stand for a few hours, then observe. It may be more convenient to let stand overnight.

a. How do the levels agree in both experiments?
b. How much difference in inches is there between the molasses experiment and the water experiment?
c. In which way has the liquid passed?
d. How do you account for the rise in one and not in the other?
e. What conclusions can you draw as to the passing of water through a membrane?
f. Did molasses pass through the membrane into the water? Test with Fehling's solution a little of the water from vessel 1. (Fehling's solution is a standard test for the sugar in molasses.)
g. What substances, then, have passed through the membrane?
h. Which passes more rapidly? Explain how you know this.
i. Do you think that grape sugar, which is a product of photosynthesis, will pass through plant membranes?
j. Write a paragraph about the experiment.

Exercise 8. A Study of Osmosis in Plant Tissues

Materials needed. Several beets; 3 tumblers.

1. Cut a beet into slices about one fourth of an inch thick; then prepare from these slices three pieces about as long and one half the width of a domino. Wash the pieces thoroughly in water so that no red sap remains on the surface of the pieces. Dry the pieces with a soft towel. Allow them to stand on a table in the air until they are flexible. Half fill each tumbler with water. Into tumbler 1 place two teaspoonfuls of salt and stir until dissolved. Tumblers 2 and 3 should contain only water. When the pieces of beets are flexible, boil one piece for several minutes to kill it. Wash thoroughly and place in tumbler 2. Place one of the pieces of beet in the tumbler containing the salt solution, and the other in the solution of clear water. Allow them to remain several hours. If desired, several pieces of beet may be used in each case.

a. Describe the experiment as you have carried it out.

2. Remove the pieces of beet from each tumbler.

a. Has a change taken place in each piece of beet?
b. What is the change?
c. What has caused the rigidity to change?
d. Tell in which direction osmosis has taken place more rapidly in each case: into the beet or out of it.
e. Is the solution in the beet of higher or lower concentration than that in tumbler 1? than that in tumbler 2? than that in tumbler 3?
f. Why does the red sap pass out of the slice of beet in tumbler 2?
g. Why does it not pass out in tumbler 3?
h. Write in your own words a description of the experiment. Draw any conclusions necessary.

CELLS, TISSUES, AND ORGANS

It will be found that this series of exercises will require the use of the compound microscope. There is no way to study cells other than with the microscope. If one is not available, all except the first exercise may be omitted. The others should be discussed after study in the text.

Exercise 9. A Study of the Plant

Materials needed. Bean seedlings about three inches high.

Examine all the parts of the seedling after washing the soil from its roots.

1. Make a drawing of the plant, natural size. Label roots, stem, leaves, cotyledons.

   a. What difference in color is there between the stems and the roots?

   b. Can you explain why there is this difference?

   c. What can you say as to the direction of growth of the various parts of the plant?

The parts of the plant which you have examined are the *organs*. The stems, roots, leaves, flowers, and seeds are all organs. Each organ has some special work to do. This work is called its *function*. All organs are made up of various kinds of tissues and cells.

CELLS

A study of the organs of a plant should include a study of the various kinds of cells which constitute them. These cells are of different types according to the functions which they perform. Some are for strengthening, some for conduction, some for protection, and in others food accumulates.

Exercise 10. A Study of Parenchyma

Materials needed. Safety-razor blade (nearly any blades will be found very satisfactory); elder or cornstalk pith; compound microscope; cover glass and slide.

1. Cut a very thin section of elder pith with a razor and mount in sufficient water to completely surround it. Cover with a thin cover glass. Examine under low power of the microscope.

a. What is the shape of the cells in the section?
b. Are they all the same size?
c. Is the shape of the whole cell a circle or a sphere?
d. Are the cells thin-walled or thick-walled?
e. What is the color of the walls?
f. Draw six or more cells.

These cells occupy most of the space not occupied by other tissues in the plant and are the type of cells in which food accumulates. Such tissue is called the *fundamental tissue*; its name is *parenchyma.*

Exercise 11. A Study of Starch Grains

Parenchyma is often filled with food in *fruits* and *tubers* which are largely of this tissue.

Materials needed. A potato; cover glass; slide.

1. Cut a potato into two pieces. In doing this many cells are cut, and their contents flow out. With a blunt knife secure a drop of this juice and place upon a slide. Dilute with a small drop of water and cover with the cover glass. Examine under low power.

a. Do you see starch grains?
b. Are there many or few?
c. What shape are they?
d. Can you see markings on their surface?
e. Describe them. Are they concentric or eccentric? The hilum is the spot near one end.

Exercise 12. A Study of Starch in Parenchyma

Materials needed. A potato; slide; cover glass; iodine.

1. Remove the peel from a potato. Cut as thin a slice of the flesh of the potato as possible. Wash thoroughly in water and mount on a slide in the usual manner. Examine under low power.

a. Note the thin-walled cells.
b. Do they resemble the parenchyma which you examined in elder pith? Are they parenchyma?
c. What do they contain?
d. What is the test for starch?

2. Place a drop of iodine at one edge of the cover glass and draw it under the cover by touching a blotter to the opposite edge.

a. Does it stain the starch? What color?
b. Does it stain the cell wall?
c. Does the cell wall contain starch?

3. Draw several cells showing the included starch grains in position.

a. Label cell walls and starch grains.

Exercise 13. A Study of Stone Tissue

Materials needed. A pear; slide; cover glass; aniline sulphate. The pear can be kept indefinitely in a 5-per-cent formaldehyde solution.

1. The pear, especially the Kieffer variety, contains a large number of "sand grains." These are called *stone cells.* Secure a small amount of pulp containing these grains. Place on a slide and stain with a drop of aniline sulphate. This stains stone cells yellow and is therefore a specific stain for them.

a. What is the shape of the cells?
b. Are the walls thick?

2. Observe the canals which run through the walls and connect with the open space in the center of the cell.

a. Do they connect with the canals in the adjacent cells?
b. What do you think the function of these canals has been?
c. Stone cells are dead. Can you suggest reasons for this?
d. Draw several of these cells enlarged. Show the thick cell walls and the canals.

3. Write a paragraph, telling in your own words what you have learned about cells (Fig. 4).

FIG. 4. A typical cell, showing cell wall, nucleus, cytoplasm, chloroplastids, and vacuoles

Exercise 14. A Study of a Typical Cell

Materials needed. An onion; compound microscope; slide; cover glass; iodine.

The cells most easily demonstrated in the onion are those in the skin which covers the concave surface of the leaves. Recall that the onion bulb is made up of a number of fleshy leaf bases, or leaf scales. Strip off one of these. Now remove the skin from the inner, or concave, fleshy surface of this leaf.

1. Examine this tissue.

a. Is it thick or thin?
b. Is it delicate or coarse?
c. What is an outer layer of the plant such as this one called?
d. What is its function?
e. Do you find the same tissue on the convex surface of the onion leaf?

2. Mount a piece of this tissue about the size of the end of your lead pencil in the usual manner and examine under the microscope.

a. Are the cells regular or irregular?
b. Are they rectangular or square?
c. If they have a long axis, in which direction does it extend?
d. What color are they?

e. Draw ten cells as you see them. Each cell should be a quarter of an inch long.

3. Stain the tissue with iodine in the usual manner.

a. What parts does the iodine stain?
b. Can you detect in each cell a dense, rounded body (the nucleus)?
c. What is the size of the nucleus in relation to the rest of the cell?
d. Can you seé the cytoplasm? This includes all the cell contents except the nucleus. Describe its appearance.
e. What are the cytoplasm and the nucleus together called?
f. What is the protoplast?
g. What is the material called which composes it?

4. If the cells are old, there may be open spaces in the cytoplasm called vacuoles.

a. Do you find vacuoles?
b. What position in the cells do they occupy?
c. What is their size compared with the total area of the cell?
d. What do vacuoles contain?
e. Draw a single cell enlarged to two inches. Indicate the cell wall by a single heavy line, dot the cytoplasm, leave the vacuoles clear, and show the nucleus as a circle with heavy dotting inside. Label all parts.

Exercise 15. A Study of Epidermal Cells and Hairs

Materials needed. A geranium leaf; microscope; slide; cover glass.

1. Remove a small piece of the epidermis from the leaf. To do this you should tear the leaf in such a manner that the epidermis will be stripped from one piece of the leaf. Mount a small piece in water in the usual way (Fig. 5).

a. Observe the irregular wavy outline of the epidermal cells.
b. Draw several.
c. Are they clear or do they contain chlorophyll?

2. Find two kinds of hairs on the leaf.
   a. Describe each.
   b. What is the function of the pointed hairs?
   c. What is the function of the glandular-tipped hairs?
   d. What is the relative proportion of the two kinds?
   e. Draw each kind enlarged.

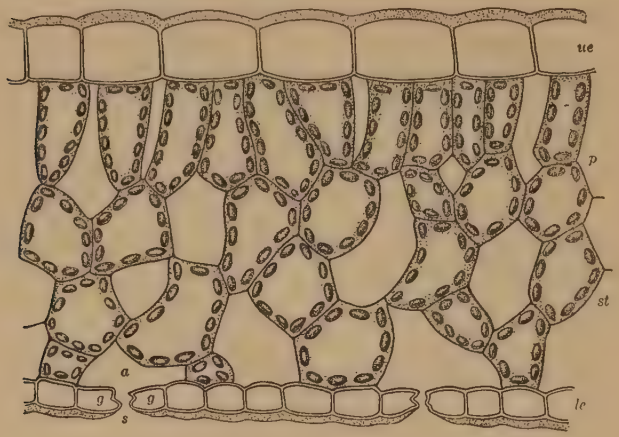

FIG. 5. Cross section of a geranium leaf

ue, upper epidermis; *le*, lower epidermis; *p*, palisade cells; *st*, sponge tissue; *s*, stoma; *g*, guard cells; *a*, air space

NOTE TO TEACHER. The cell and its contents can generally be made clearer by comparing it to a violin case and its contents. The violin case is analogous to the cell wall, and the violin is analogous to the protoplast. The violin is composed of several materials; the protoplast is composed of protoplasm. The protoplasm is composed of cytoplasm and nucleus; the violin is composed largely of wood and string.

Exercise 16. A Study of Cell Division

This study will be impossible unless prepared slides of onion roots are available. A single slide would be of great value to demonstrate this process to the student.

You have already studied a normal cell in the epidermis of the onion leaf. Prepared slides of the onion root are made

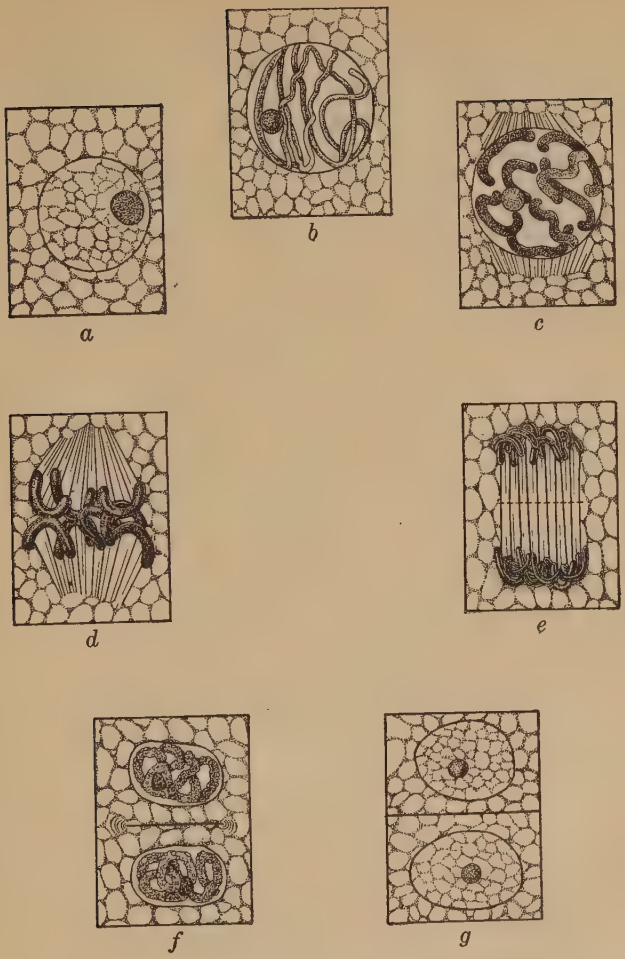

FIG. 6. Cell division, or mitosis

a, a resting cell; *b*, a cell in which the chromatin is forming into a spireme; *c*, the spireme broken into chromosomes; *d*, the splitting of the chromosomes; *e*, the chromosomes after they have pulled apart and moved to the poles; *f*, the formation of the cell wall between two organizing nuclei; *g*, two daughter cells exactly like the original cell in *a*

by an intricate process of fixation and staining which requires special preparation on the part of the person who makes them.

1. Study the slide under the instruction of the teacher.

a. Do you find cells in which the nucleus is dividing?
b. Do you see chromosomes?
c. Can you find arrangements of chromosomes which correspond to those in Fig. 6?
d. Study the slide carefully. Do you find new cell walls forming?
e. Are any daughter cells visible?

2. Early stages in nuclear division will show the chromatin as a long, tortuous thread. When the nucleus is cut into two pieces in the preparation of a slide, the chromatin thread may show only cut ends, which give the nucleus the appearance of being filled with dots.

a. Do you find such nuclei?
b. Is the nuclear membrane still present?
c. Do you find the spindle in dividing nuclei?

3. Draw various stages in cell division. The student should be familiar with the section on mitosis in the textbook. Only such drawings as the teacher directs should be made.

TISSUES

Aggregates of cells which perform a particular function are called *tissues*. It is cells, then, that are the basis of tissues and it is tissues that form *organs*. The vascular tissues, the veins of the leaf, the covering of the leaf, and the bark are examples of tissues.

Exercise 17. A Study of Vascular Tissue

Materials needed. Plantain leaves; several stalks of celery; cornstalk.

If living plantain leaves are available, they make excellent material to demonstrate vascular tissue. If these leaves are not available, secure some celery or a cornstalk.

1. Pull a plantain leaf so that it breaks into halves crosswise.

a. Do strings pull out of the ends where the veins show?
b. What are these strings? What is their function?
c. Try to break one. Are they tough or brittle?
d. What tissues make up vascular bundles? (See Pool and Evans's "First Course in Botany," pp. 20, 21.)
e. Of what cells is wood composed?
f. Of what cells is bast composed?

2. Break a stalk of celery. (This is part of a leaf.)

a. Does it contain strings?
b. What tissue composes these?
c. Do they extend the whole length of the stalk?

3. The tissue between the vascular bundles is parenchyma.

a. What makes it so brittle? Does it contain food?
b. Allow a piece of celery to lie exposed in the sun for a time. Does it remain brittle? Why? What does parenchyma contain? Now place the celery in water for a time. Does it recover its brittleness? How does it do this?

4. Strip the hard outer layer from a cornstalk. This will leave the pith exposed. Remove a piece of pith from the stalk.

a. Does it break readily?
b. Do you notice bundles running through it?
c. What are these bundles? Are they all the same size?
d. Are they most abundant (that is, closest together) near the edge of the stalk or near the center? Put a thin razor section of pith under the microscope, mounted in the usual manner.
(1) What type of cells do you find composes it?
(2) Are they thin-walled?
(3) What function do you think they perform?

UNDERGROUND PARTS OF PLANTS

A STUDY OF ROOTS

Two kinds of roots are common among plants: *taproots* and *fibrous roots*. In plants which have a taproot the stem appears to continue into the ground as a central axis from which branch roots arise. This is a common type of root in many of our annuals. In such plants as the carrot, parsnip, and beet, large quantities of food accumulate in the root, which becomes fleshy (Fig. 7).

The fibrous roots are slender, threadlike roots which arise from the base of the stem. These roots grow through the ground in all directions. The blue grass, the foxtail, and the corn plant have this type of root system.

Exercise 18. A Study of a Taproot

Materials needed. Ragweed roots; bean-seedling roots.

1. Secure specimens of ragweed and wash the soil carefully from them.

a. Do you find that they have a thick central root?
b. Do the branch roots come off in order?
c. Are the branch roots distributed throughout the length of the taproot or are they confined to certain areas?
d. Draw a taproot system of the ragweed.
e. Cut a ragweed root across. Draw such a cross section.
f. Can you distinguish the cortex? the central woody area?

2. Plant some Lima beans and allow the roots to become several inches long. Wash the soil from the roots and study them.

a. Do the branch, or secondary, roots come off in order?
b. If there is an arrangement, explain it.
c. Draw a diagrammatic cross section of the root showing the order or arrangement of the secondary roots.
d. Draw the root system of a bean.

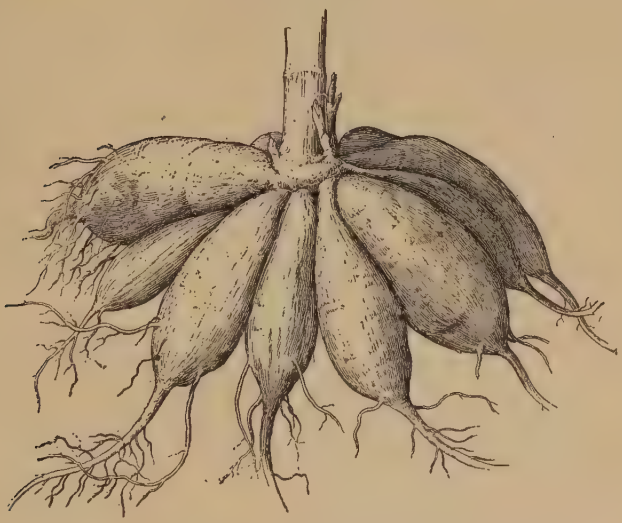

FIG. 7. The fleshy and clustered roots of dahlia

Exercise 19. A Study of the Fleshy Taproot

Materials needed. A carrot; a beet.

1. Secure a carrot and study it carefully.

a. Does it have secondary roots?
b. Are they given off in order?
c. Are they large or small compared with those of the ragweed?
d. What is the color of the root?
e. To what is the color of carrots and tomatoes due?
f. Why are carrots of value as food?
g. What happens to the carrot root during the second year?
h. Draw a carrot.

2. Cut a carrot across and note the layers. If possible, make the cut through a secondary root.

a. Do you distinguish an outer layer? This is the cortex, and it is covered by a single layer of cells, the epidermis.
b. What name is applied to the inner layer?
c. Why is it not tough and woody?
d. Draw the cross section carefully.
e. Where does the secondary root which you have cut through arise?

3. Make the same observations and drawing on a beet.

Exercise 20. A Study of the Fibrous Roots

Materials needed. Foxtail or blue grass; corn seedlings in various stages.

1. After washing the root system of foxtail, study it carefully.

a. Do the roots all arise from the same point?
b. Are the roots all the same size?
c. Are they tough?
d. Draw such a root system, including a short piece of the stem.

2. Study the root system of a corn seedling.

a. Draw a corn seedling which has a plumule about an inch long. The single large root from near the tip of the kernel is the primary root. Those from the side are secondary roots. These roots are all temporary and are later replaced by a permanent root system.
b. Label all parts carefully.

3. Secure an older corn seedling in which the secondary root system is appearing about an inch above the seed.

a. Draw the seedling, showing the temporary and permanent root systems.
b. What happens to the temporary roots?
c. What happens to the kernel of corn?

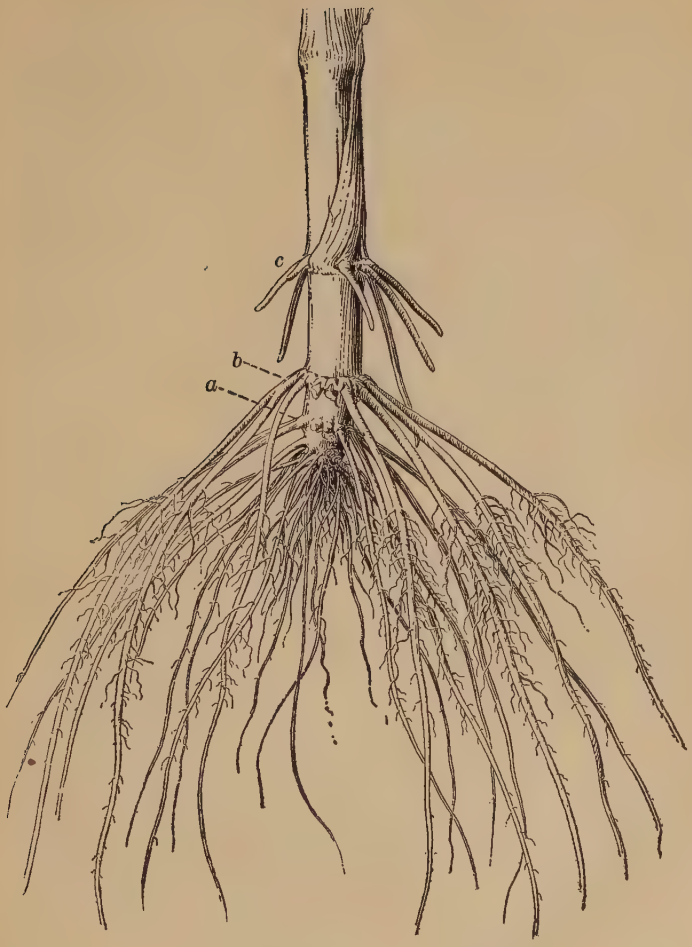

FIG. 8. The fibrous roots of a corn plant

Note the brace roots at *a*, *b*, and *c*. Those from *a* and *b* have entered the soil and developed branches

d. State which you think is the more important: the temporary root system or the permanent root system. Explain.

e. Note the swelling, or joints, on the stem. These are called nodes. The part between two nodes is called an internode. Label the nodes and internodes in your drawing of a corn plant.

f. What happens to the permanent roots?

g. Do roots have nodes and internodes?

Exercise 21. A Study of Root Hairs

Materials needed. Young radish or corn seedlings grown between blotters and others grown in soil.

1. Plant some radish seeds between two moist blotters. When they have grown two or more inches in length, examine the roots for root hairs.

a. Do you find root hairs?

b. If so, where are they located?

c. Do you find them equally distributed over the root?

d. If not, where are they lacking?

e. How do you account for this?

f. How long are they compared with the width of the root?

g. What color are they?

h. Draw a radish seedling, showing the root hairs.

2. Insert a knife below the radish seedlings growing in soil and loosen so that they may be removed carefully.

a. Does the soil adhere to the roots?

b. Explain your answer, telling why it adheres.

c. If the soil adheres, does it do so to all parts of the root?

d. Draw such a seedling.

e. What is the value of fine root hairs to the plant?

f. Are they complete cells or only extensions of the epidermal walls?

g. Why are they limited to the tip of the root?

h. Write a paragraph on root hairs, telling how they are developed and the advantages to the plant.

Exercise 22. A Study of a Rhizome

Material needed. Quack-grass rhizomes.

1. Dig up the underground parts carefully. If quack grass is not available, brome grass, Johnson grass, Western wheat grass, or any grass which has creeping underground stems may be used.

a. How deep do the rhizomes that you have dug grow?
b. Would you say they were a deep or a shallow organ?
c. Is their position in the soil horizontal or vertical?
d. Do they grow as a network in the soil or otherwise?

2. Carefully shake off the soil which clings to the parts.

a. Does a rhizome have nodes and internodes?
b. Is a rhizome a root or a stem? How do you know?
c. Does it give off branches? Where?
d. Does it develop roots? Where?
e. Notice carefully the scalelike organs at each node. What are they? (See Pool and Evans's "First Course in Botany," p. 191.)
f. Why are they thin, membranous, and without chlorophyll?

3. The rhizome is primarily a *reproductive organ.* It is a very successful means of reproduction; for each part of a broken rhizome will reproduce the plant, provided it bears a node.

a. Are the nodes close together or far apart?
b. Of what advantage is this in reproduction?
c. Why is the position that the rhizome takes in the soil advantageous?
d. Of what disadvantage to the plant is a thick mat of rhizomes near the surface? The student should think of this in terms of the amount of water and food present.
e. Would you suggest deep or shallow plowing to kill the rhizomes?
f. Would you suggest plowing it in dry weather or in wet weather?

g. What would be the result of shallow plowing (that is, just deep enough to get below the mat of rhizomes) in dry weather? in wet weather?

h. What would be the result of deep plowing in dry weather? in wet weather?

i. Explain how the stand may actually be thickened by plowing at the wrong time.

4. Write a paragraph in your own words explaining why quack grass is successful, and tell how you would go about combating it. If necessary, write your state experiment station for information.

Exercise 23. A Study of Underground Creeping Rootstocks

Materials needed. Underground rootstocks of Canada thistle; May apple; sow thistle; leafy spurge, or any other plant which develops such a rootstock (Fig. 9).

1. Study an underground rootstock of a May apple.

a. Is it composed of nodes and internodes, as is a rhizome?

b. Do roots have nodes and internodes?

c. Where do the branch roots appear?

d. Where do new shoots develop?

e. Are the new shoots only developed at the beginning of the season or at any time?

f. Give any evidence you can discover to support your stand.

g. Which is the oldest part of the rootstock? Label it.

h. What evidence have you that leads you to such a conclusion?

i. Draw enough of a rootstock to show all the parts discussed.

j. What characteristics distinguish the rootstock from a stem? from a rhizome?

2. Plants with rootstocks are hard to eliminate in many cases. The Canada thistle, the sow thistle, and the leafy spurge are very persistent.

a. Why are such plants so hard to eliminate?
b. Is such a rootstock a good reproductive structure?
c. Give several points in evidence to support your answer.

3. In eliminating such plants a handful or two of salt placed about the base of the plants will usually kill them, because it destroys young shoots and roots. If young shoots do not develop, the plants die.

a. Why should the rootstocks die when the parts aboveground do not develop?
b. Can you suggest other methods of eliminating such plants?
c. Would the rootstocks die if the top were consistently kept from showing green tissue aboveground? Explain.
d. Can all plants be destroyed by this method?

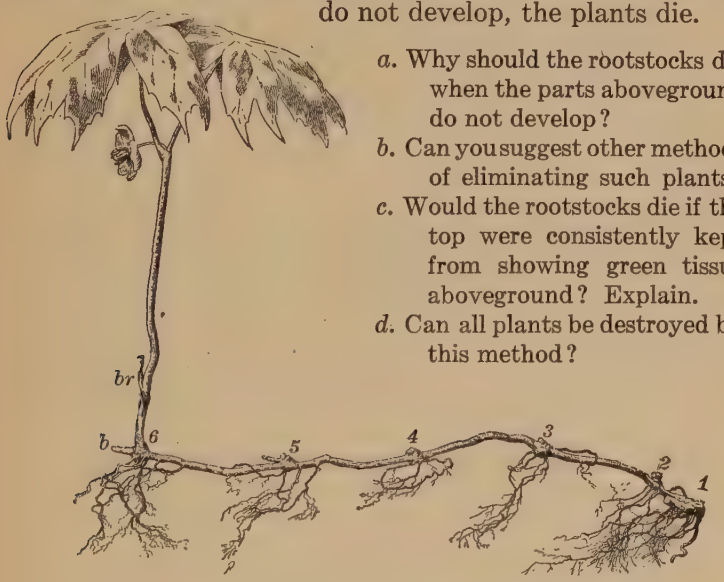

FIG. 9. A May-apple rootstock, showing six years' growth

b, bud which will give rise to seventh year's growth; *br*, a bract at the base of present stem

Exercise 24. A Study of a Potato Tuber

Material needed. Potato tubers (Fig. 10).

1. Carefully examine a potato tuber, noting the "eyes," stem end (the point where it is attached to the plant), bud end (the opposite end), and its general form, shape, and color.

a. What are the "eyes" of a potato? Examine them carefully with a hand lens.

b. What can you say about the buds which you can see?
c. How many are there?
d. Is there any particular grouping of the buds?
e. Why do potato "eyes" sometimes put out more than one sprout?
f. Draw a potato with the bud end up.
g. Draw an "eye" enlarged. Show the buds which compose it.
h. Do roots have buds?
i. What conclusions do you draw as to whether the tuber is a stem or a root?
j. Why is a tuber often thought of as a root?

Exercise 25. A Study of a Bulb

Material needed. An onion bulb. The onion is a good example of a bulb. It is easily obtained and readily understood. The onion is largely composed of the bases of the old leaves, which have become enlarged because of the accumulation of food within them. The top part of the leaves dies and falls away. The basal portions of the leaves are called leaf scales.

1. Examine a medium-sized onion carefully.

a. Does it have a protective coat?
b. Is it thick or thin?
c. Does the bulb grow above or below ground?
d. Draw an onion bulb, side view, about natural size.

2. The onion bulb has a very short, vertical stem. Split the onion in two vertically and examine the cut face.

a. Can you see the short stem?
b. What is its relationship to the height of the whole onion bulb?
c. Do the roots come from the base of this stem or from some other point?
d. What is the advantage of a vertical stem?
e. Can you distinguish each leaf?
f. Are they thickest at the top, at the middle, or at the bottom of the leaf scale?

g. Can you account for the shape of the bulb?
h. Draw a view of the cut face of the onion bulb.
i. Remove all the leaves from an onion. What is their shape? What is the shape of the stem?

Exercise 26. A Study of a Corm

Materials needed. Corm of crocus, gladiolus, or jack-in-the-pulpit. Any one of these is very good.

1. Secure a dry corm of gladiolus. The corms are usually more or less rough and vary in size from that of a marble to that of a hen's egg. We have just learned that an onion is a bulb with a very short stem covered with many scale leaves which are filled with food materials. The corm is the very opposite. It is a thick stem filled with food materials and with a few scattered small leaves attached to it. These leaves remain as dry brown scales which detach readily from the corm, leaving a circular mark upon it. When they are removed, the corm appears smooth. Study the corm closely.

FIG. 10. A potato, showing "eyes" which are made up of a number of buds

a. What is its shape? Is it smooth or rough?
b. What is its color? Does the color vary?
c. Is it firm or soft? Of even or uneven texture?
d. Are leaves present? In what condition?
e. Describe their size, shape, location, and general appearance.
f. Draw a corm, showing and labeling all parts.
g. Split the corm and draw the cut surface. Label stem and leaf bases.
h. Write a paragraph distinguishing between a corm and a bulb, also giving the main points that you have learned.

Exercise 27. A Study of Root Tubercles

Materials needed. Young legume plants (clover, alfalfa, cowpeas, beans, peas, or any other legume may be used). Unless grown in soil which has grown the crop before, nodules may not be present.

1. Secure plants of one or several of the above and wash the soil thoroughly from the roots.

a. Do you note small swellings, or tubercles, on the roots? (See Pool and Evans's "First Course in Botany," pp. 47, 185.)
b. Explain how these are formed.
c. How large are they? Draw a small rootlet with two or three tubercles. Enlarge several times.
d. How many are on the plant that you have examined?
e. Of what value are these tubercles?
f. Do they harm the legume plant?
g. If not, do they benefit it?
h. Can you suggest a means by which tubercles can be established on a plant?
i. Do plants other than legumes have them?
j. Draw a plant, showing the tubercles.

2. Legume plants are valuable in a rotation because they form these tubercles.

a. What happens to the tubercles when the plant dies?
b. Where do legumes get the nitrogen which they fix?
c. Can you suggest a good rotation that takes advantage of legumes and their nitrogen-fixing power?
d. Write a paragraph on the value of legumes.

Exercise 28. A Study of Aërial Roots

Material needed. A mature cornstalk. Cornstalks can easily be secured in most places in September. Any field will yield proper material on search.

1. Find a cornstalk with the so-called brace roots, or aërial roots, coming out from the first or second node aboveground.

a. Where do the brace roots appear?
b. Do they come from above the point of leaf attachment or below it?
c. Do they grow through the leaf sheath?
d. Are they located on one side of the stalk or all round it?
e. Do they grow into the soil?
f. Describe their shape.
g. Draw the base of a plant showing these roots.

2. Secure some of the aërial roots which have entered the soil.

a. What happens when they enter the soil?
b. Do they anchor the plant?
c. Do you think they absorb water?
d. Draw a single aërial root which has grown into the soil.

Exercise 29. A Study of Roots of Plants

Material needed. Read several references on roots. You will find that roots have numerous functions in plants. Many of the most interesting have not been discussed.

1. Name all the types of roots that you can.
2. Name all the underground parts of plants that you can.
3. Give all the functions performed by those parts you have named in question 2.
4. Roots have several functions.

a. Name as many functions of roots as you can.
b. Tell, from the studies you have made, which roots absorb water and nutrient salts: the large roots near the base of a tree or the smaller roots and root hairs.
c. If you were going to water a tree of large size, should the water be poured near the base or out from it? Explain the reason for your answer.
d. Is the wilting of a plant an indication of the amount of water in the soil?
e. Write a page or more about roots, discussing them fully on the basis of what you have learned.

LEAVES

Leaves play an important part in the manufacture of food. They are a *thin, flat green expanse* of *tissue* containing *chlorophyll.* Most of the *photosynthesis* of the plant occurs in the leaves. Leaves are of variable size and shape and are arranged upon the stem in a number of ways suited to their best display. Leaves have veins running through the blades. The arrangement and disposition of the veins is called *venation.* Venation is of two types: *netted-veined,* in which the veins are much broken up; and *parallel-veined,* in which the veins run approximately parallel the full length of the leaf. The maple leaf and the geranium leaf are examples of netted-veined leaves; the corn leaf is an example of a parallel-veined leaf (Figs. 11 and 12).

TYPES OF LEAVES

Entire Leaves

Exercise 30. A Study of a Cottonwood Leaf

Material needed. Cottonwood leaves.

1. Study a cottonwood leaf. It is an example of a netted-veined leaf.

a. What is the shape of the leaf?
b. What is the shape of the apex?
c. What is the shape of the base?
d. Does it have a midrib? Heavy or light?
e. Does it have secondary veins? How many?
f. Explain the venation.
g. Does the leaf have teeth?
h. If so, what is their shape?
i. Draw the leaf in detail, showing the serrate teeth.

2. The leaf stalk, by which the leaf is attached to the twig, is called a *petiole.*

a. Is the petiole round or flat?
b. Is it longer or shorter than the blade of the leaf?
c. Why is the petiole swollen at the base?
d. Do you think the midrib is a continuation of the petiole?

FIG. 11. Palmately-veined leaf of a maple
s, sinus; *l*, lobe; *p*, petiole

3. In quaking aspens the petiole is always flat and is usually longer than the blade of the leaf. Examine such leaves if possible.

a. Can you give a reason why these leaves tremble in the slightest breeze?
b. Would a leaf with a round petiole tremble in the same breeze?
c. Is there advantage in leaves which tremble in light breezes? (See The Book of Knowledge, Vol. 15, p. 5366.)

Exercise 31. A Study of an Elm Leaf

Material needed. Elm leaves.

1. Examine several elm leaves.

a. In what way do they differ from cottonwood leaves?
b. Are they the same shape?

FIG. 12. Palmately-veined leaf of a geranium

c. Are the teeth alike?
d. How do the bases differ? The base of the elm leaf is said to be asymmetrical. Can you account for this?
e. How does the venation differ? This type of venation is called *pinnate*, which means "like a feather."
f. Is the petiole longer or shorter?
g. Can you think of any reason why the petiole of the cottonwood should be so much longer? If necessary, get a

branch from each of these trees and note the arrangement on the stem.

h. What is the shape of the leaf?

Exercise 32. A Study of a Geranium Leaf

Material needed. Geranium leaves.

1. Study a leaf of the geranium.

a. What is its shape?

b. How does it differ in its venation from the elm and the cottonwood?

2. This type of venation is known as *palmate,* from the fact that the veins extend out from the base of the leaf like the fingers from a palm.

a. How many veins are there?

b. Are some larger than others?

c. Do they run to the margin of the leaf?

d. What is the shape of the margin? This type of margin is called *crenate.*

e. Is the petiole long or short? Explain.

f. Draw a leaf, showing all parts.

In many leaves the margin is lobed instead of being entire; that is, there are broad, shallow notches in it. This may occur in either *palmately-veined* or *pinnately-veined* leaves, in which cases they are *palmately-lobed* or *pinnately-lobed.*

Exercise 33. A Study of an Oak Leaf

Material needed. Oak leaves.

1. This is an example of a pinnately-lobed leaf. Note the margin and its venation.

a. What is the type of venation?

b. Is the margin entire?

c. How deep are the notches? These notches are called *sinuses*; the part between two sinuses is called a *lobe.*

d. Draw the leaf and label all parts.

Exercise 34. A Study of a Soft-Maple Leaf

Material needed. Soft-maple leaves.

1. This is an example of a palmately-lobed leaf. Observe the shape of the margin and the venation.

a. What is the type of venation?
b. Where do the veins unite?
c. How many main veins are there?
d. Do they extend to the tips of the lobes?
e. How many lobes are there?
f. How deep are the sinuses compared with the width of the leaf?
g. Draw a maple leaf and label its parts.
h. Does the length of petiole vary in different maple leaves?
i. Explain the reason why this is true.

Compound Leaves

In many leaves the sinus extends to the midrib or base of the leaf, thus breaking the leaf into a number of leaflets. This represents the greatest division possible and may occur in both pinnately divided and palmately divided leaves. In pinnately divided leaves the leaf is said to be *pinnately compound* (Fig. 13); in palmately divided leaves it is said to be palmately compound.

Exercise 35. A Study of a Honey-Locust Leaf

Material needed. Honey-locust, alfalfa, bean, pea, or Siberian-pea leaves will do.

1. Study a honey-locust leaf. This is an example of a pinnately-compound leaf. Note the arrangement of the leaflets upon the central stalk, which is the *rachis*.

a. How many leaflets are there?
b. Does each leaflet have a midrib?
c. To what does this correspond in the elm?
d. Are the leaflets opposite each other?

e. Draw a complete leaf. This leaf is divided until each part has become a separate little leaf called a *leaflet.*
f. Of what advantage is such an arrangement?
g. Does a honey-locust tree cast much shade?
h. Do you see any possible advantage in this? Explain.

Exercise 36. A Study of the Leaf of the Virginia Creeper

Material needed. Virginia-creeper or woodbine leaves.

1. Examine small leaves of the Virginia creeper. This is an example of a palmately-compound leaf.

a. How many leaflets are there?
b. Where are they attached?
c. Does each have a mid-vein?
d. To what does it correspond in the maple?
e. After examining this leaf can you explain why the veins in the maple run to the tip of the lobes?
f. Does the sinus run completely to the base?
g. Of what advantage is such an arrangement of the leaf into leaflets?
h. Draw the entire leaf.

FIG. 13. A honey-locust leaf

2. Write a paragraph, telling what you have learned concerning leaf shapes, venation, and modifications of leaves.

Exercise 37. Effect of Lack of Water on Plants

Material needed. Four potted plants. Beans may be planted and be used for this experiment when they have reached a height of about six inches. Nearly any available

plants may be used, but they must be about the same size and about the same age.

1. Place two of the plants under the same conditions of light and heat. Water one each day, but do not water the other. Watch the plants carefully.

a. What happens to the plant which is not watered?
b. How long did it take? Does the watered plant wilt? Why?
c. Describe the appearance of each plant.
d. To what is wilting in plants due?
e. Sketch the wilted and non-wilted plants that you have just studied.

2. After the plant has wilted, supply it with water. Do not allow the wilting to proceed too far.

a. Does the plant recover?
b. How quickly does it recover after water is supplied?
c. Does the wilting seem to have injured the plant?
d. Is wilting of any value to the plant?
e. Have you noticed wilting in plants out of doors during hot summer days?
f. To what is it due?
g. Will plants die that wilt and remain wilted too long? Experiment by using the plants which you have for that purpose.
h. How long after wilting began did it take the plants to reach a point where they would not recover?
i. Can you determine how much moisture is present when the plant wilts? (See Pool and Evans's "First Course in Botany," pp. 46, 47.)

3. Although wilting is primarily due to lack of moisture in the soil, it is materially aided by the loss of water from the leaves by transpiration.

a. Why do plants which have wilted during the day recover during the night?
b. Will they wilt the following day if the sun is bright?
c. Would they wilt if it were cloudy?
d. Explain why this is so. (See encyclopedia.)

4. With the other two plants perform the following experiment, making sure that for several days before the experiment the plants have received the same amount of water. Cover one with a glass jar and leave the other free. Do not water the plants after beginning the experiment.

a. Is water formed on the sides of the jar?
b. Do you think the uncovered plant gives off water also? Prove it.
c. What becomes of the water?
d. Tell which plant *transpires* more rapidly: the covered or the uncovered.
e. Explain the reasons for your answer.
f. Allow the experiment to run until one plant wilts. Which wilts first?
g. Why does not the other wilt as soon?
h. How much longer does it take the covered plant to wilt, if it does so at all?
i. Do you think cloudy weather might act as a means of lowering the rate of transpiration? Why?
j. Where does water used by plants come from?
k. How does it get into the plants?
l. Read several references on transpiration. Write an essay on the subject.

Exercise 38. A Study of Stipules

Material needed. Red-clover or alfalfa leaves.

1. Secure a leaf of alfalfa or red clover. In removing it be careful to get those parts which adhere closely to the stem. These are the *stipules.*

a. How many stipules are there? What is their position?
b. Are they large or small? Size in parts of an inch?

2. In many plants, such as the willow, the stipules fall away, and at a later stage there is no trace of them.

a. Do the stipules of the plant you are studying remain attached to the petiole?
b. Do they appear to be deciduous; that is, dropped?

3. Find another plant which has stipules and bring it to class for similar study.

a. Write a paragraph about stipules after you have studied them.

Exercise 39. A Study of Leaf Arrangement

Material needed. Soft-maple or lilac twigs, catalpa twigs, plum twigs, or spiræa twigs. The twigs studied need to be young and should be upright in growth; otherwise the leaves may have become twisted out of position.

1. Study a slender young twig of the soft maple or the lilac. If it is in winter condition, remember that the leaves bear the buds in their axils. Leaves can therefore be located readily. In this study, consider only the point of attachment of the petiole to the leaf and not the position of the blade.

a. How are the leaves arranged at the nodes? This is called *opposite* arrangement.
b. Examine the node next above. Are the leaves above those at the node below?
c. If not, explain their position.
d. Study the third node. In what position are the leaves attached with reference to those below them?
e. Why do we not consider the position of the leaf blade rather than the attachment to the stem?

2. Secure a horizontal branch of an elm or a maple and view it from above and from below.

a. What can you say as to the arrangement of the leaf blades?
b. Do they extend out in all positions from the stem?
c. If not, how are the leaves displayed?
d. Can you think of any reasons why this should be as it is?
e. If a branch were gradually turned over and tied so that the leaves were forced downward, do you think that the leaves would change their position?
f. Explain what you think would happen. Try this, if it is possible.

g. Of what advantage, if any, is leaf arrangement to a plant?
h. Tell what parts of the plant are active in the orienting of a leaf to light.
i. Draw a twig, showing opposite arrangement.

3. Study a branch of the catalpa if it is available.

a. How are the leaves arranged at each node?
b. Are the bases of the leaves an equal distance apart?
c. What part of the circumference are they apart?
d. What is the position of the leaves with relation to the leaves at the next node above? at the second node above?
e. What advantage do you see in this?
f. Draw a catalpa twig, showing the leaf arrangement at three nodes.

4. Secure an upright twig of spiræa or plum. Tie a thread about the base of a leaf. Now carry the thread to the base of the next leaf above, going by the shortest distance; that is, to the right or to the left, as the case may be. If you have gone counterclockwise round the stem, continue the thread in the same direction to the succeeding leaves until the thread touches a leaf which is directly over the leaf with which you started. If you have started the thread clockwise, then continue in that direction as directed above. When you have finished, the thread should pass round the stem like a stripe about a barber's pole, touching each leaf in succession as it passes upward.

a. Does the thread go clockwise or counterclockwise; that is, to the right or to the left?
b. How many times have you passed the thread round the stem before finding a leaf exactly above the one with which you started?
c. How many leaves has it touched before reaching the one exactly over the first? Of course, this one should not be counted, since it is the first leaf in the next series above.
d. What is the shape of the course of the thread about the stem? This is called *spiral* arrangement.

e. If the thread passes twice about the stem, and there are five leaves in the spiral, it is called the *two-five arrangement* (written 2/5). The numerator refers to the number of spirals about the stem and the denominator to the number of leaves before another is met in the same position as the one with which you started. In a similar manner we have one-three and three-eight arrangements. (See Pool and Evans's "First Course in Botany," p. 60.)

f. Do you believe this method is successful in displaying leaves to the light?

g. What is the advantage of such an arrangement?

h. Write in your own words a paragraph about leaf arrangement, including any observations you have made.

Exercise 40. A Study of Leaf Mosaic

Material needed. The class should be taken to see Virginia creeper or ivy growing over the side of a building. If this is not available, study dandelion rosettes, morning-glories on a trellis, rambler roses, clematis, or any other plants which are lighted from one side. Beans may be planted in winter and kept in the dark for a day in the two-leaf state. When brought out before a well-lighted window they should respond well in four or five hours. (See Pool and Evans's "First Course in Botany," p. 77.)

1. Visit a building covered with Virginia creeper. Stand at some distance and observe it.

a. Can you see the wall if you are looking toward it through the leaves?

b. Look up at an angle of 45°. Can you see the wall?

c. At what angle does the leaf blade stand?

d. What holds it in this position?

2. Get as close to the wall as you can. Look up along the wall. Select places where the foliage is not too dense.

a. Do the leaf blades stand out from the wall?

b. If so, about how far?

c. What can you say of the petioles?

d. If there are leaves close to the wall, why?
e. Are they young leaves or old leaves?
f. Such a pattern of leaves as shown by Virginia creeper on a wall is called a *mosaic*. Do you think it is efficient in getting all the light?

3. If you study morning-glories, clematis, or roses, view them from the direction of the sun.

a. Do many leaves face the sun?
b. Are all the leaves directed in the direction of the sun?
c. Explain your observations.
d. If possible, observe the plant from the opposite side. Record your observations.

4. Place some bean seedlings in the two-leaf stage in the dark in the late afternoon. Bring them out the following noon and place them about six feet from a well-lighted window. Observe them from time to time during the afternoon.

a. Do the leaves respond?
b. If so, in what way?
c. In what length of time?
d. How do they respond? Describe the means by which they have responded.
e. Is it the petiole or the stalk that bends?
f. Draw the bean when it is first placed in the light.
g. Draw it after it has responded.
h. Do you think plants are sensitive to light?
i. Why do you think they are or are not sensitive?

5. Now turn the plants so that they face in the opposite direction.

a. Do they respond?
b. How long does it take them to reach the upright position?
c. How long does it take them to reach the position which they occupied before turning them about?
d. Write a paragraph on the response of seedlings to light. Include in your discussion a suggestion as to the probable cause of such action. Read a few good references.

6. Look down on a number of small plants such as ragweeds, potatoes, phloxes, and others (Fig. 14).

a. What do you observe concerning the leaf arrangement?
b. Study the arrangement on a lilac bush and write your observations.

FIG. 14. View looking down vertical shoot of syringa

The leaves are arranged in pairs at right angles to the pairs above and below. This is called *opposite arrangement*

FIG. 15. Leaves of a familiar clematis, showing the petioles twisted to serve as a tendril

7. Stand near the trunk of a large tree with a dense canopy of leaves. Observe the position of the leaves by looking up through the branches. Such trees as the hard maple, catalpa, elm, soft maple, and similar types are excellent for this study. Cottonwoods are not good as a rule.

a. Which way do they face?
b. Where are most of the leaves borne?
c. Are there many leaves in the central part of the tree?
d. Why do you think this is so?
e. Is there likely to be more light near the center or near the tips of the branches? Why?
f. Observe the same tree from above; from a window, if possible. Record your observations.

8. Write a short essay on "Leaf Arrangement as an Efficient Means of displaying Leaves to Light" (Fig. 15).

Exercise 41. The Stomata of Leaves

Materials needed. A geranium or any other convenient leaf; cover glass; slide; compound microscope.

In leaves there are openings through the epidermis known as *stomata.* It is through stomata that carbon dioxide enters the leaf and gases and water escape from it (Fig. 16). It is the too rapid passing of water through stomata from the leaf that causes the wilting which we recently studied (Fig. 17).

1. Tear the leaf in such fashion that the epidermis is peeled back. Mount a piece of the epidermis in water and observe under low power of a microscope.

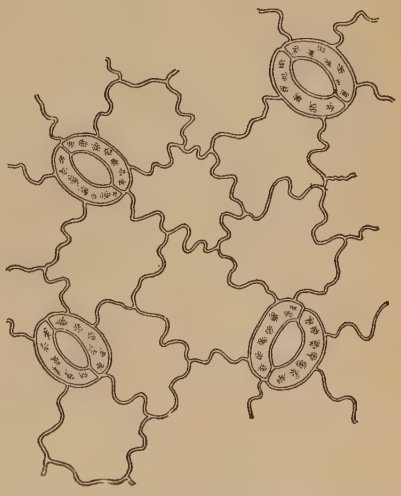

FIG. 16. Epidermal cells of a geranium leaf, showing wavy outline of cells and four stomata with guard cells containing chloroplastids

a. Do you see the stomata?
b. Do you observe the guard cells about them?
c. How many are there?
d. Do the guard cells have chlorophyll?
e. Do you observe any other epidermal cells which have chlorophyll?
f. Draw a single stoma, enlarged, showing guard cells with chlorophyll.
g. How many do you observe in the field under low power?
h. What are the functions of stomata?
i. How many cells border each guard cell?
j. What happens when the sun shines on a guard cell?
k. Does it lose water rapidly?
l. Does loss of water close the stoma? With what effect?

Exercise 42. A Study of Cutin

Cutin is a waxy, waterproof material over the outside of leaves. It keeps the leaf from losing water rapidly on dry hot days.

FIG. 17. A young cucumber plant, showing how it wilts when left unwatered several days

Plant at left, normal; at right, wilted

Materials needed. A cabbage plant; a century plant or evergreen leaves of fir or spruce.

1. Note the white "bloom" over the surface of each leaf. Rub it with your finger.

   a. Does it rub off?
   b. Is it grown fast to the leaf or is it only superficial?
   c. Why does water run off cabbage plants so readily or form in drops over the leaves when they are sprinkled?

2. Observe the cabbage plant or the century plant several days later and from time to time thereafter.

a. Does this "bloom" come back?
b. If so, how do you think it is renewed?
c. Do you think it may be of value?
d. Do cabbage leaves wilt readily on hot days?
e. Explain your answer, giving reasons why you think this is so.

3. Arrange a flowerpot with two small plants in it. Bean seedlings will do very well. Coat the leaves of one very lightly with vaseline and leave the other without. Be sure to select plants which do not have cutin on the leaves. Allow the plants to go without water until one of them wilts.

a. Which wilts first?
b. Can you give a reason?
c. What possibly may have slowed down transpiration?
d. How?

4. Corn leaves roll on very hot days in summer.

a. Why do you think they do this?
b. How may it slow down transpiration?
c. Which way do corn leaves roll, up or down?
d. Where are the stomata located on corn leaves? (See Pool and Evans's "First Course in Botany," p. 62.)
e. Why do you think they are so placed? Note the position of the midvein before deciding.
f. Where are the stomata on most leaves located? Why?

Exercise 43. Do Leaves Manufacture Starch?

Materials needed. Any broad-leaved plant; two pieces of cardboard, tinfoil, or other opaque substance; two clamp-type clothespins; iodine.

1. Cut out two pieces of opaque material of any desired shape, preferably about the size of a quarter. You may cut your initial in the center of one, if you wish. Place the plant to be used in the dark for a day or more before starting

the experiment. This allows all starch to be removed from the leaf. To test whether starch is present or absent remove a leaf and place in iodine. If starch is present, it will turn blue-black. Is starch present? If it is absent, place one of the disks on the top of the leaf and the other on the bottom. The one with your initial should be on the top of the leaf. Now clamp the disks on carefully with the clothespins. Of necessity the disks must be near the edge to be held securely by the clothespins. Set the plant in the sun for one or two hours, then remove the leaf and place it in a solution of iodine. The starch will be colored blue-black.

a. Is starch present?
b. In what part of the leaf?
c. Is there starch in the initial? Why?
d. Do you conclude that leaves manufacture starch?
e. Under what conditions?
f. Write a paragraph on photosynthesis, which is the manufacture of starch by plants. Describe the experiment fully.

NOTE. Occasionally trouble is experienced in staining starch with iodine purchased at the drug store. If made up as follows, one can be certain that it will be effective:

0.5 gram potassium iodide
0.5 gram chloral hydrate
3 to 5 cc. tincture of iodine
¾ pint distilled water

TRANSPIRATION AND GUTTATION

Exercise 44. Does Water Escape from the Leaves of Plants?

Materials needed. Two small potted plants; two glass tumblers or bell jars.

1. Place one of the plants under the bell jar and allow it to remain overnight. Observe in the morning.

a. Is there moisture on the sides of the jar?
b. Where do you believe it came from?

c. If you believe it came from the soil, pour melted paraffin over the soil, being careful not to burn the base of the plant. This can be avoided by wrapping a piece of paper loosely about it for protection. The paraffin must not be too hot. Does moisture still appear in the jar when the plant is covered with it for a time?

d. What is the escape of water from leaves in this fashion called?

2. Water the second plant abundantly and keep it in a very warm place, preferably near a radiator. When it has been in such a warm place overnight or at least several hours, remove it to a cool place and watch it for a number of minutes.

a. Do drops of water appear on the leaves?

b. If so, where?

c. Where have they come from?

3. The plant in the heat with an abundance of water took up much of the water. Upon removal to a cool place the roots continued to take it up and the leaves to throw it off; but because of its being cool, the water condensed on the leaves near the tips, where there are small openings. This is called *guttation.*

a. Does water pass out of leaves?

b. How do you know?

c. Where does it come from?

d. Do leaves give off much water? (See Pool and Evans's "First Course in Botany.")

e. Write in your own words a paragraph about the escape of water from leaves.

Exercise 45. Is Carbon Dioxide Necessary for the Manufacture of Starch in Leaves?

Materials needed. Two potted plants (small geraniums will do very well); two trays; potassium hydroxide; two bell jars large enough to cover the plants.

1. Place the plants in a dark room for twenty-four hours so that all the starch will disappear from the leaves. At the end of the twenty-four-hour period test a leaf from each plant for starch. Is starch present? If so, return the plants to the dark room for another period and until a test of the leaves shows no starch.

2. Place potassium hydroxide to the depth of about two inches in the first tray. Place in the center of the tray a support, such as an inverted beaker, and upon this rest one of the potted plants so that the flowerpot does not touch the potassium hydroxide. Now cover the whole with a bell jar, being careful that the edges of the jar are well covered by the potassium hydroxide. Arrange the second tray with its plant the same as the first in every respect except that tap water should be used instead of potassium hydroxide.

a. What will be the effect of potassium hydroxide on the air within the bell jar? If you do not know, ask your teacher or, better still, discover it for yourself.

b. Will all carbon dioxide be removed from it?

c. Will tap water remove carbon dioxide from the air about the second plant?

3. Place the plants as arranged in a dark room for twenty-four hours to allow time for absorption of the carbon dioxide by the potassium hydroxide. At the end of twenty-four hours expose the plants to sunlight for three hours. Be sure that your experiment is set up correctly.

a. After exposure in sunlight test a leaf from each plant with iodine. Does either contain starch?

b. Describe the experiment in writing and draw your own conclusions as to why the experiment has resulted as you have observed.

c. Do you conclude that carbon dioxide is necessary for the manufacture of starch?

d. Draw the apparatus as you have it set up.

e. Write a paragraph on your observations.

Experiment 46. Do Plants Give off a Gas when Starch is Manufactured?

Materials needed. A piece of elodea, a small water plant; test tube; vessel of water. If you do not have this plant, a small amount can be purchased from almost any supply house. The plant must be alive and in a good active condition for best results.

1. Fasten the sprig of elodea to the bottom of the vessel so that it stands upright in the water. It may be weighted in this position. Fill a large test tube with water and invert it in the vessel so that all air is excluded from it. Now slip the test tube over the elodea. Place the whole in direct sunlight. Soon a gas will be given off by the plant and will collect in the top of the test tube. Collect a quantity; then test for oxygen.

a. Is it oxygen? How should one test for oxygen?
b. How do you know? What experiment has taught you this?
c. What is your conclusion?
d. Draw the apparatus used.
e. When do plants release oxygen?
f. Do you think that plants would be beneficial in a living room?
g. Explain your answer.
h. Write a paragraph giving your findings in this experiment.

THE STEM AND ITS WORK

Not all plants have large stems. In those that have large stems the stem connects the root with the leaves. Any materials from the soil must traverse it to reach the leaves, where food is manufactured. Stems vary in size, shape, rigidity, and many other important features. The main function of stems is to *support* and *display* the leaves; the other activities are largely incidental.

TYPES OF STEMS

Some stems are very short, as in the dandelion; others are very tall, as in trees; some are very thick in diameter, as in oaks and maples; others are slender, as in the sunflower. Large stems are covered with bark that is brown and dead. This is the condition in many perennial plants, such as trees. In annuals the bark is often green and capable of manufacturing food. All young stems, even stems of trees, are green for a time, however, and so manufacture food.

In stems the exchange of gases through the bark takes place through loose corky areas of cells called *lenticels* (Fig. 18).

Exercise 47. A Study of Bark

Material needed. Trees such as the maple, hickory, walnut, birch, cherry, hackberry, plum, and any others may be used. This study should be carried on out of doors, although large branches of various types may be used for laboratory study.

1. Study the bark on a maple.

   a. Is it thick or thin?
   b. Does it scale off?

c. Why do you suppose it is so rough? Recall that the cambium layer gives rise to wood on the inside and to bark on the outside. (See Pool and Evans's "First Course in Botany, p. 21.")
d. Are the ruptures in the bark straight or irregular?
e. What becomes of the bark when it falls from the tree?
f. What would happen if bark were not replaced beneath as the old bark ruptured?
g. Would it be disadvantageous to the tree? Why?
h. Is there bark on all the limbs as well as on the trunk?
i. Is it rough?
j. Does it vary in thickness?
k. Where is the bark the thinnest on the tree?
l. How do you account for the smooth bark on young twigs?
m. How do you account for the smooth bark of the cherry, birch, and the sycamore?

FIG. 18. Lenticels in the bark of a tree

The cherry and the birch have lenticels as illustrated

2. Secure a small twig of the maple, preferably one which is still green. Sprouts which grow up from the base of the tree make excellent specimens.

a. Is the bark thin?
b. Is it smooth or rough?
c. Do you find small, loose areas of cells (the lenticels)?
d. What is the shape of a lenticel?
e. What is its function?
f. In what direction on the stem does its long axis extend?
g. How abundant are the lenticels?
h. Do you find them on all branches upon which the bark is smooth?
i. Look for evidence of them on the trunk. What are your conclusions?
j. What organ of the leaf has the same function as a lenticel?
k. Draw a portion of a branch, showing lenticels.

Exercise 48. A Study of the Bark of the Hackberry

Material needed. Hackberry trees.

Make the same study of the bark as for maples. Note especially the smocking effect of the bark, also how tightly it sticks to the tree. If hackberry trees are not available, use ash or any other tree which has a bark similar to the hackberry.

Exercise 49. A Study of Birch or Cherry Bark

Material needed. Birch or cherry trees.

1. Examine closely the birch or cherry bark. The directions are for the birch.

a. Is the bark smooth or rough?
b. Does it grow up and down the tree, as in the maple?
c. If not, how does it grow?
d. Strip off a little of the superficial bark to find this out. Be careful to remove only a small amount. It is wrong to strip off the bark indiscriminately from birches, as this injures them. No doubt you will see the results of such work evident on the trees that you are examining. What is your conclusion as to the method of growth?
e. May this account for rough and smooth bark in trees?
f. Do you find lenticels?
g. Where are they located?
h. Are they present in old twigs as well as in young twigs?
i. Is it not possible that the same is true of all trees?
j. Why, in many cases, do we not find lenticels in old bark?
k. Draw a small area of a birch trunk.
l. Do you conclude that bark, at least the outside layers, may grow around the tree?
m. Do the deeper layers of the bark grow up and down or in circular fashion?
n. Does the outer circular bark conduct water?
o. If not, why not?
p. What may be its function?
q. Is it thick or thin as compared to the total bark?

Exercise 50. A Study of the Stem of a Dicotyledon

Material needed. Very young twigs of any tree. Maples are excellent. Other twigs, such as those of the box elder, are suitable.

1. Cut a cross section of a twig with a sharp knife or a razor.

   a. Examine the end of the twig with a hand lens. Do you see the pith?
   b. What can you say of its appearance compared with the rest of the stem?
   c. Pick the pith with a needle. Is it soft or firm?
   d. What part of the whole stem is occupied by the pith?

2. Examine the rest of the stem outside the pith.

   a. Do you recognize the woody area?
   b. Is it a thick or a thin cylinder? Examine several.
   c. Is it harder or softer than the pith?
   d. The phloëm may be recognized lying just outside the wood as the inner layer of the bark. Can you see it?
   e. The epidermis is the single layer of cells on the outside of the twig. It will probably not be seen with low magnification. Between the epidermis and the phloëm is the cortex, which makes up the rest of the bark.
   f. Draw a view of a cross section of the maple stem.

Exercise 51. A Study of the Stem of a Monocotyledon

Material needed. Stem of a green corn plant; stem of an adult corn plant.

1. Strip the leaves carefully from the stem.

   a. Does the stem have joints or nodes?
   b. Where are the leaves attached?
   c. What is the part between two nodes called?
   d. Are the stems round or otherwise?
   e. If not, explain.
   f. Are all internodes alike in their arrangement, shape, length, etc.? Explain any variations you may note.

2. Cut a young stem across.

a. Describe a cross section of the young stem.
b. Is it hard? Where?
c. Where is it soft?
d. What are the thread-like bundles running through it?
e. What can you say of the vascular bundles in corn?
f. Are they in a solid cylinder, as in maples?
g. Then what is the arrangement?

3. Cut an old stalk of corn across.

a. Do you see the vascular bundles?
b. Do they run through the pith?
c. Is the pith a large or a small area in the stem of corn?
d. Draw a cross section of a corn stem.

Exercise 52. A Microscopic Study of a Cross Section of Clematis Stem

Materials needed. A clematis stem about one sixteenth of an inch thick; compound microscope; cover glass; slide; aniline sulphate. If a clematis stem is not available, use some other woody climbing plant.

1. Study carefully the clematis stem.

a. Is it round?
b. If not round, what shape is it?
c. Does clematis grow as a tree, a shrub, or a vine?
d. How does it climb?
e. Does it have tendrils?
f. What part becomes the tendril?

2. Cut as thin a cross section of the stem as is possible with a sharp razor. It is often advisable to cut the section in such a manner that the blade passes out of the material before it reaches the opposite side. This gives a section that is very thin on one edge. Be careful to cut the sections as nearly straight across the stem as possible. Slanting sections are of no value in this study. It is recommended

that the teacher cut the sections several days before they are needed (Fig. 19). Drop the sections as cut into a small dish containing aniline sulphate. This will stain the wood and stone cells bright yellow. The pith, phloëm, cambium, medullary rays, cortex, and epidermis will remain clear. If the sections are mounted in a drop of glycerin, they may be kept indefinitely.

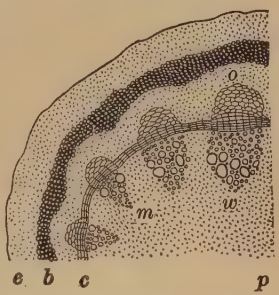

FIG. 19. Diagrammatic cross section of one quarter of one-year-old stem of Dutchman's-pipe

e, region of epidermis including cortex; *b*, hard bast, or stone, cells; *c*, four vascular bundles with a line of cambium passing through them; *o*, phloëm part of the vascular bundle; *w*, xylem part of the vascular bundle; *m*, medullary ray, one of which appears on either side of the vascular bundle; *p*, the pith. (Magnified 15 times)

a. What is the arrangement of the vascular bundles?

b. What three tissues constitute a vascular bundle?

c. How many vascular bundles are in the section which you have?

d. Are there any stone cells?

e. If so, where?

f. Can you see the epidermis?

g. Are the medullary rays distinct?

h. What is their position?

i. Draw a diagram of half a section four inches across the base. Indicate the limits of the vascular bundles by a circle. Dot the xylem, but leave the phloëm clear. Show the cambium as a line. Make the stone cells a solid black. Indicate the epidermis by a line. Draw the medullary rays as radial lines between the vascular bundles. Fill in all other space by lines parallel with the base line. This is called *horizontal hatching*. These lines should be about one sixteenth of an inch apart.

j. What parts are horizontally hatched?

3. Draw ten or more cells of each of the following tissues: epidermis, cortex, sclerenchyma, phloëm, cambium, xylem,

medullary ray, and pith. Draw all cells accurately. They should be greatly enlarged.

a. Are pith cells thick-walled or thin-walled?
b. Are the walls of xylem thick or thin?
c. Is phloëm thin-walled or thick-walled?
d. How do the walls of sclerenchyma compare with those of xylem? with those of phloëm?
e. Are the cells of the cortex more like xylem or pith?
f. Tell what type of cells you think these are: parenchyma, collenchyma, sclerenchyma.
g. Describe, in your own words, a cross section of clematis stem.

Exercise 53. A Study of the Age of Twigs

Material needed. The ends of a number of young twigs of the maple, either in winter or summer condition.

1. Examine the young twigs carefully.

a. Do you find roughened areas of the bark at intervals along the twigs?
b. The distance between each of these represents a year's growth. How many years old is the twig you have?
c. The green portion represents the amount of growth during the present season. How long is it?
d. How does it compare with the past year's growth? with the other years' growth?
e. The roughened areas are the scars of old bud scales. Can you determine this by examining with a lens?

2. Examine the twigs of other trees and determine whether or not the same conditions prevail. Record your results, as for the maple.

Exercise 54. A Study of the Age of Trees

Material needed. Stumps of trees or cross sections of tree trunks. Two or three cross sections of tree trunks about a foot or two long and a foot or more in diameter should be kept as permanent material in the laboratory.

1. Examine the end of a log for variations. Each ring represents a year's growth (see Fig. 20).

a. Do you find rings?
b. How many?
c. How old do you think the tree was?
d. If the tree has just been cut, when was the seed planted?
e. What is the cause of the rings? (See Pool and Evans's "First Course in Botany.")
f. Are the rings wider near the center of the log or near the edge?

FIG. 20. Cross section of a stem eight years old

Note the bark. Beneath the bark will be seen the cortex followed by eight layers of wood. The pith occupies the center

g. How do you account for this ?
h. Are all the rings the same width?
i. What is the shape of an annual ring? Remember that you are viewing only a cross section.
j. Draw a diagram of a cross section of a log, showing the annual rings.
k. Do you find heartwood and sapwood?
l. What is the reason for the formation of heartwood and sapwood?
m. Are they living or dead? Explain each.

Exercise 55. A Study of Buds

Material needed. Twigs of the lilac, cottonwood, or chestnut with buds in the winter condition. Such buds may be preserved for use in a 5-per-cent solution of formaldehyde.

1. Secure a large bud of a lilac. Study it carefully.

a. How are the bud scales arranged?
b. Is the bud round? If not, what shape is it?
c. Are the scales arranged in pairs?
d. What is the relationship of each pair?

2. Remove the bud scales and place them on the table in the order removed.

a. Are the scales protected by wax? Examine cottonwood buds.
b. What would be the advantage of wax in such a case?
c. How many pairs of bud scales are there?
d. What do you find after all the bud scales are removed?
e. Into what do these grow?
f. Are bud scales efficient in protecting young growing points?

3. Split a bud lengthwise with a sharp razor and draw a face view of the cut edge.

a. What is the function of a bud?
b. Into what may a bud develop?
c. What statement can you make as to the position of buds?
d. What can you say of the arrangement of branches?
e. Why are they so arranged?

Exercise 56. A Study of Types of Branching

Materials needed. Elm, soft maple, hackberry, ash, box elder, or cottonwood; also evergreen trees.

There are two types of branching in trees: the deliquescent, in which the main trunk gives rise to a series of smaller branches and eventually is completely lost; and the excurrent, in which the trunk continues as a central columnar stem to the top of the tree. It gives off branches at intervals, but they are always smaller, and the main trunk is never lost.

The Deliquescent Tree

1. Study a number of deciduous trees: the elm, soft maple, hackberry, ash, box elder, or cottonwood. Note the

form, size, branching, and other characteristics of the tree. Record each tree separately.

a. Is the trunk long or short?
b. What determines the length of a tree trunk?
c. Do the limbs that grow out of the trunk near the ground ever rise appreciably above that level? Explain your answer.
d. Does the trunk divide into large branches? How many?
e. Do these subdivide?
f. Do all the branches spread widely or do they often remain close together after dividing?
g. What is the general shape of the tree?

FIG. 21. A beech that has fallen, owing to shallow root system over rock

Photograph by H. T. Thompkins. Courtesy of the United States Forestry Service

2. Select a symmetrical tree standing alone and view it from a distance.

a. What is the shape of the tree on top?
b. Is it round, topped, or pointed?
c. What is the shape of the base of the tree; that is, the part from the top down to the point where the trunk begins to branch? It may be indicated as square, round, wedge-shaped, etc.
d. Are the branches given off in regular or irregular fashion?

The Excurrent Tree

1. Study a specimen of Colorado blue spruce, white spruce, fir, Norway spruce, or Douglas spruce.

a. Is the stem continuous through the center of the tree?
b. Does it give off branches?
c. In what way do the branches differ from those given off by the elm or the maple?

d. How do the lower and upper branches compare in length?
e. Why is there this difference?
f. What is the shape of the top of the tree? of the lower part?
g. What is the shape of the whole tree?
h. What is the difference in the leaves of the deliquescent and excurrent stems?

Exercise 57. A Study of Accessory and Adventitious Buds

Materials needed. Trees which have been pruned the previous season; stumps of recently cut trees; branches of horse-chestnut, walnut, or butternut.

The regular terminal and lateral buds continue the growth of branches, produce leaves, and develop flowers unless inhibited or injured. Often a bud may be broken off or be prohibited from developing in some other way. For such emergencies many plants have buds called *accessory buds* (Fig. 23). If frost damages the first shoots, others start from the accessory buds. In other cases a branch may be cut off. Numerous small shoots may develop near the end. They come from *adventitious buds*. Such buds are developed from meristematic cells near the point of cutting.

FIG. 22. An evergreen tree in which two terminal buds have developed

1. Observe numerous branches that have been pruned back.

a. Do you find any with sprouts near the cut surface?
b. Do you think the sprouts are from the regular axillary or lateral buds? Why do you think so?
c. Is there more than one sprout?
d. Would this indicate adventitious buds?
e. Of what advantage are adventitious buds?
f. Of what disadvantage are they?
g. Why do many woody plants cut off at the level of the ground develop sprouts?
h. Do you think that roots develop adventitious buds?
i. Draw a stem, showing shoots developed from adventitious buds.

2. Secure twigs of the horse-chestnut or one of the other trees suggested. Examine the axillary buds.

a. Do you find a leaf scar?
b. Where is the bud located in relation to it?
c. Is there more than one bud?
d. How many are there?
e. Which do you think is the axillary bud?

3. The second bud is the accessory bud.

a. Is it as large as the axillary bud?
b. What is the advantage of it?
c. What do you think happens to accessory buds when they do not develop?
d. Draw a stem, showing the leaf scar and axillary and accessory buds.

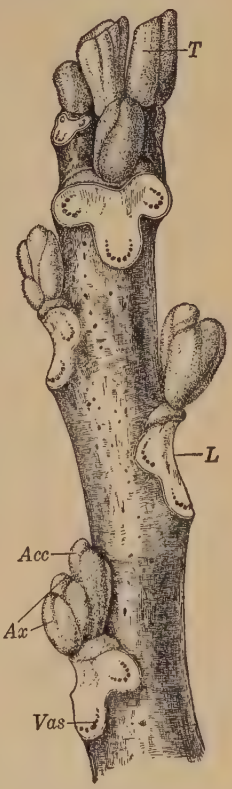

FIG 23. Twig of butternut

The leaf scars are prominent. Note the arrangement of the vascular-bundle tips (*Vas*) upon the surface of the scars (*L*). Above each scar are the axillary buds (*Ax*) and an accessory bud (*Acc*). The terminal buds (*T*) continue the growth of the twig. (Redrawn)

Exercise 58. A Study of Climbing Plants

Material needed. Any climbers of the following types, as clematis, English ivy, Virginia creeper, grape, morning-glory, sweet peas, rambler rose.

FIG. 24. Grafting

At the left the scion and stock are shown ready to be united; at the right they are joined and ready to be covered with grafting wax. (After Percival)

Weak-stemmed plants may climb in a number of ways. They may find support by coiling about other plants or supports, they may clamber over other vegetation or supporting structures, or they may support themselves by tendrils or root-like adhesive pads.

1. Examine any or all of these plants. Study the methods utilized in finding support.

   a. Which of them climb by coiling about the support? (Do not mistake training by gardeners for natural coiling.)
   b. In which direction do they coil: clockwise or counter-clockwise?
   c. Do they coil tightly or loosely about their support? Notice both recent and old coils.
   d. If there is a difference, how do you account for it?
   e. What is the result when the supporting plant increases in diameter?

2. Note the other plants which are available.

   a. Which plants support themselves by adhesive pads?
   b. Where are such pads given off?
   c. What do you think the structure may have been?
   d. Try pulling several off at one time. Do they offer a satisfactory means of support?
   e. Draw a node, showing the mode of attachment.

3. Study those plants which have no special means of support, such as the rambler rose.

a. How does it obtain support? In most cases the rambler roses studied are likely to have been trained on trellises, so due allowance must be made for this.

b. State which is the more efficient way of getting to light where vegetation is dense: by coiling, or by the means which is utilized by the rambler rose.

4. Observe the tendril climbing of the grape, clematis, and sweet pea.

a. What part in each becomes the tendril?

b. Do the tendrils coil about the support? Why?

c. How does the tendril become formed into the spring-like condition?

d. Of what advantage is this?

Exercise 59. A Study of Budding or Grafting

If time permits, it would be well to let each student try budding some convenient plants. If this is done, they will have a far better idea of the process.

Materials needed. A knife sharp as a razor (safety-razor blades may do); raffia; plum trees; peach trees.

Read the discussion on "Budding or Grafting" in Pool and Evans's "First Course in Botany." With this well in mind and a clear idea from the picture (Fig. 24), the student should proceed under the direction of the teacher.

A STUDY OF FLOWERS

Most students think of the science of botany as a study of flowers. This is far from the fact. Flowers do play an important rôle in the study of plants, but many other studies are necessary, as we have seen, to complete a course in modern botany.

The flower is a very essential part of the plant, for it is through the flower that the plant is reproduced (Fig. 25). Then, too, flowers are attractive, and for that reason alone are likely to maintain the attention of more people than any other part of the plant.

Exercise 60. A Study of a Nasturtium

Material needed. Nasturtium flowers.

1. A typical flower is composed of a flower stalk called the *pedicel*; a *receptacle* (which is the enlarged upper part of the pedicel); a *calyx* composed of *sepals*; a *corolla* composed of *petals*; a number of *stamens* each composed of a *filament* (stalk) and *anther* (the pollen receptacle); and a *pistil* or *pistils* composed of *ovary, style,* and *stigma.* Learn these parts of the flower correctly. Do not be misled by color, since colors do not necessarily distinguish parts. Very often we think that only petals are colored, but this is not always true.

Drawings should be of reasonable size. Better to draw too large than too small. Make all parts clear. Study the nasturtium flower carefully.

a. At what angle is the flower arranged on the flower stalk?

b. Do you find that this flower has sepals? How many?

c. Do you see the spur, a long tubular part extending downward from the flower? What does it contain? What is its function?
d. Does the nasturtium have petals? How many?
e. Are they all alike?
f. What are the combined petals called?
g. What are the combined sepals called?
h. What part or parts form the spur?
i. How long is the spur?
j. Draw a side view of the nasturtium, looking obliquely into the center. Label fully.

FIG. 25. Flowering stem of a mustard plant

Notice the progressive development from buds (*b*) at the top, open flowers (*f*), and falling flowers (*a*) in the center to mature seed pods (*p*) near the bottom

2. Remove the sepals and petals carefully, one at a time, and place them on the table before you.

a. Are all the sepals the same shape?
b. Are all the petals the same shape?
c. Explain the shapes.
d. What do you think may be the reason for their varying?
e. Draw each of these parts.

3. Study the stamens and pistil after you have removed the floral parts.

a. How many stamens are there?
b. How many pistils are there?
c. Remove and draw a stamen enlarged to one inch.
d. What are its parts?
e. Remove some pollen from an anther and draw under high power of the microscope.
f. Remove and draw a pistil enlarged to one inch.
g. What are its parts?
h. Does it have one stigma or more than one?
i. What is the function of a stigma?
j. What is the function of a style?

k. What is the function of an ovary?
l. Tell whether the ovary is inferior or superior; that is, is it within the corolla or below it?

4. Write in your own words a paragraph, telling what you have learned about this flower.

Exercise 61. A Study of a Flower of the Sweet Pea

Material needed. Sweet-pea flowers.

The sweet pea is a *legume* and is very similar to other legumes, such as beans, clovers, alfalfa, and peas. The flower is somewhat complicated, but is not difficult to understand.

1. Examine the sweet-pea flower carefully (Fig. 1).

a. Does it resemble a nasturtium flower?
b. If not, how does it differ?
c. Draw a side view, showing pedicel, calyx, and corolla.
d. What color is the calyx?
e. Is it a tube, or are the sepals separate and distinct?
f. Is it smooth or hairy?
g. How many parts do you think compose it?
h. How can you tell?

2. Study a corolla carefully.

a. Do you find a broad upper petal? This is called the *standard.*
b. Do you find two petals, one on each side, just below the standard? These are called the *wings.*
c. Do you see a basal petal which is shaped like the keel of a boat? This is called the *keel* and is really made up of two petals. Sometimes these are separate. Do you find any which are separated? Notice the base of the two petals which compose the keel. Is there a notch in it? This shows where they have joined.
d. Remove the petals in the order given and draw each somewhat in the position in which they were removed. Label each.

3. Draw the parts that remain after removing the petals.

a. How does the calyx appear?
b. Do you see the loose ends of the stamens with the anthers attached?
c. Do you find them united into a tube lower down?
d. Look carefully at the stamen tube. Is it a cylinder or is it split down one side?
e. How many stamens are there?
f. Are all united into the tube?
g. If not, explain how many are and how many are not.
h. Draw the parts, side view, as you have found them from this study.

4. Remove the stamen tube carefully.

a. Do you find a part within?
b. What is it?
c. What is its shape?
d. Into what will it develop in a sweet pea? in a garden pea? in a bean?
e. Draw the pistil as you see it.
f. Does it curve up toward the standard or away from it?
g. Does it curve toward the slit in the stamen tube or away from it?
h. Is the ovary inferior or superior?

5. Write a paragraph about the sweet-pea flower. Read about this flower in Pool and Evans's "First Course in Botany."

Exercise 62. A Study of a Clematis Flower

Material needed. Clematis flowers. If clematis is not available, hepatica, anemone, or any other flower lacking one of the floral parts will do equally well.

The student should recall from the reading in Pool and Evans's "First Course in Botany" that not all flowers have both calyx and corolla. When but one of the floral parts is present it is considered to be the calyx.

1. Study a clematis flower carefully.

a. Are both calyx and corolla present?
b. Which one is considered present?
c. What are the parts present considered to be?
d. What parts of a flower may be colored?
e. What name is applied to the floral parts of flowers?
f. Draw the flower somewhat in face view to show all the parts.

2. Remove the floral envelope and study the parts left.

a. What parts do you find?
b. Are there many or few stamens?
c. Are there many or few pistils?
d. Each pistil is called a *carpel.* What are its parts?
e. Into what does each ovary develop?
f. Are the ovaries inferior or superior?
g. Are such plants as clematis many-seeded or single-seeded?
h. Draw a single mature seed of the flower studied.

3. Write a paragraph about clematis, giving points you have learned.

Exercise 63. A Study of a Snapdragon

Materials needed. Snapdragon flowers; a few pins.

The snapdragon is a common flower of our gardens. It is peculiar and interesting because of the mouth-like arrangement that leads to the stamens and pistil.

1. Study the whole flower.

a. How do you find it differs from the flower of the sweet pea?
b. Are the petals united or separate? This is called a *tubular corolla.* The flower is said to be *sympetalous.*
c. Draw the flower in side view. Show the calyx and the corolla.
d. Is the mouth of the corolla open or closed?
e. Do you think small insects that eat pollen may get into this flower?
f. What kind of insects can enter?
g. Study this flower in a garden, if possible, noting some of the insects that enter it.

2. Remove the corolla by pulling upon it gently. Split it down one side, spread it out, and fasten with pins.

a. Are there parts adhering to the corolla?
b. What are they?
c. How many? (Sometimes one of them does not have an anther.)
d. Draw the corolla spread out, as you have it.
e. What parts are left on the flower stalk?
f. Remove the calyx and draw. Label all parts.
g. Is the ovary inferior or superior?

3. Cut the ovary across with a sharp razor. If it is a large ovary, you will see the ovules. Examine with a hand lens.

a. Do you see ovules?
b. Are there many?
c. To what are they attached?
d. The partition to which they are attached has a swelling through the center called the placenta. This is called a central placenta.

4. Secure as large ovaries as are possible and carefully cut slices of them. You should be able to see a cross section of the placenta plainly. (See Pool and Evans's "First Course in Botany" concerning placentæ).

a. Into how many parts is the ovary divided?
b. What are these chambers called?
c. Draw a sketch of a cross section of this ovary.

5. Write a paragraph on the snapdragon.

Exercise 64. A Study of a Rose Flower

Material needed. Rose flowers; apple blossoms, hawthorn blossoms, or the blossom of any pome convenient. They may be preserved in 5 per cent formaldehyde for use during the winter.

All the flowers thus far studied have had the ovaries within the corolla and therefore superior. In the rose

flower the ovary is half-inferior; that is, the floral parts grow up about the ovary, but do not completely surround and inclose it.

1. Carefully examine the flower furnished you.

   a. Draw it, face view.
   b. Can you determine where the stamens and petals are attached?
   c. Do they appear to grow out of the calyx?
   d. Are there few or many stamens? How many?
   e. How many petals are there?

2. Draw a side view of the flower.

   a. Can you see the ovary below the floral parts?
   b. Into what does this ovary develop in the rose? in the apple? in the pear?
   c. Split the flower perpendicularly and draw a view of the cut surface.
   d. Do you see the seeds?
   e. From what are they developed?

3. Write a paragraph about half-inferior ovaries, as seen in the rose.

Exercise 65. A Study of a Pumpkin Flower

Material needed. Pumpkin flowers; cucumber flowers; muskmelon flowers or any other large flower with an inferior ovary. The honeysuckle is very good (Fig. 26).

Pumpkin flowers are hard to get unless the study is made in the fall or unless the flowers are raised in the greenhouse.

1. Examine the flower. Locate the ovary.

   a. Is it inferior or superior?
   b. Can you see the ovary when you are looking down into the flower, as in the rose?
   c. Draw a flower with inferior ovary, side view.
   d. Split the flower and ovary lengthwise, then draw the cut surface, labeling all parts.

Any other flowers may be studied, as time permits. It is suggested that such flowers as the alfalfa, sunflower, willow, primula, and others be taken up for additional work and to lead the student to discover new facts for himself.

POLLEN

The pollen is that part of the plant contained in the anthers and is essential for the fertilization. It is a light-yellow dust, the grains of which are microscopic in size. Sometimes it is sticky, and the grains adhere together. In wind-pollinated plants it is very abundant and powdery. If opportunity affords, dust into your hand one of the staminate flowers of the pine or the upper end of one of the cat-tails which grow so abundantly about ponds and note the amount and texture of the pollen.

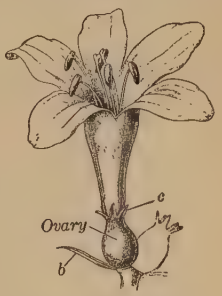

FIG. 26. Flower of a honeysuckle, showing inferior ovary

b, bract; *c*, sepals

Exercise 66. A Study of Pollen

Materials needed. The pollen of several plants; cover glass; slide; compound microscope.

Pollen may be gathered in the fall and placed in small vials for future study; corn, pine, dandelion, sunflower, and many others are available at that time.

1. Mount a small amount of pollen in water on a slide. Cover with the cover glass and examine under both low and high power of microscope.

a. Do you see pollen grains?
b. Is pollen a shapeless dust or are the grains definite in structure?
c. Do you think they are very large?
d. Are there markings on the walls?

e. Draw four or five pollen grains of each variety furnished.
f. Where must pollen grains alight to pollinate a plant?
g. Can you think of any reason for pollen grains being rough-walled?
h. Do you believe many pollen grains from a pine or any other wind-pollinated plant really reach the ovaries of other pines and therefore become active in fertilization?
i. What becomes of those that do not?

Exercise 67. A Study of a Dichogamous Flower

Material needed. Old and young flowers of nasturtium or other available flowers that are dichogamous (Fig. 27).

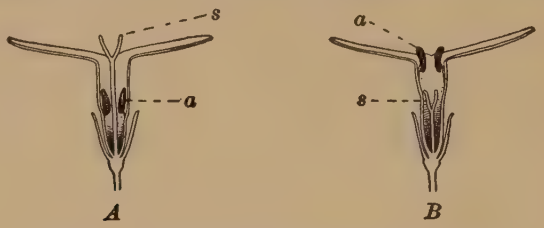

FIG. 27. Lengthwise sections of bluet flowers

The flowers of this plant are of two forms (dimorphous): *A*, long-styled form; *B*, short-styled form. *s*, style; *a*, anther. (Enlarged)

1. Examine the stamens and the pistil of a young flower.

a. Are the stamens erect?
b. Is the pistil developed?
c. Could the pistil be fertilized readily by the pollen of these stamens? Why?
d. Remove the floral parts and draw the stamens and pistil in the same relative position in which you find them.

2. Examine the stamens in an old flower. Compare with a young flower.

a. What is the position of the stamens in such a flower?
b. Are they straight or curved?
c. In what manner?
d. Is the pistil developed?

e. Does it stand in the position which the stamens formerly occupied?

f. Would a bee cross it or brush against it in entering or leaving the flower?

g. Of what advantage is dichogamy to a flower?

h. Is cross-pollination always thus insured?

i. What is the advantage of cross-pollination?

j. Draw the old flower with the floral parts removed. Show the arrangement of the stamens and the pistil.

FIG. 28. Fertilization in a flower

The grain pollen (*pg*) is shown on the stigma. A pollen tube (*pt*) has grown down to the embryo sac. The end of the pollen tube is shown passing through the micropyle and coming in contact with the embryo sac. Three nuclei are to be seen in the tube; two are sperms and one is the tube nucleus. The embryo sac has three nuclei at either end and two uniting in the middle. The largest one near the end of the pollen tube is the egg and upon fertilization by a sperm will form the embryo. The two uniting near the middle of the sac when fertilized by a sperm form the endosperm, which often surrounds the embryo

Exercise 68. A Study of an Embryo Sac

Materials needed. Prepared slides of lily ovaries showing ovules containing embryo sacs; compound microscope.

If prepared slides are available, a study of the embryo sac (Fig. 28) can be profitably studied in a simple fashion.

1. With the aid of a hand lens study a lily ovary.

a. Can you see the ovary easily? Cut a cross section of it with a razor blade.

b. Do you see the ovules within it?

c. How many can you see?

d. This is only a cross section. Are there more ovules in an ovary than those which you see?

e. Draw the ovary and the ovules as seen under low magnification.

2. Locate an ovule under low power of the compound microscope (use a prepared slide for this study). Has it an embryo sac? If not, locate one which has.

a. Do you see the stalk of the ovule?
b. Do you see the micropyle?
c. Can you locate the embryo sac?
d. How many nuclei does it have?
e. How are they grouped?
f. Can you locate the egg?
g. How is it to be distinguished?
h. Do you see the endosperm nucleus?
i. Into what does the egg develop when fertilized?
j. Into what does the endosperm nucleus develop when fertilized?
k. How many sperms are developed from a pollen grain?
l. With what do they unite?

3. Draw an embryo sac, showing all its parts. It should be two inches long and proportionately wide.

SEEDS AND FRUITS

Seeds and fruits are always the result of fertilization in flowers. Seeds cannot develop unless fertilization occurs. Fruits are developed subsequent to seed. The seeds are a means of propagating the plant. Since they contain an embryo which is well protected by being inclosed within the seed, they are admirably fitted to carry this delicate structure through unfavorable conditions of both temperature and moisture. Many fruits serve to attract animals, especially birds, by which the seeds are widely scattered. In many instances man has by selection developed fruits that serve as food.

Exercise 69. A Study of a Bean Seed

Material needed. Lima-bean seeds.

1. Carefully examine several Lima-bean seeds. If these are soaked in water for an hour before they are used, they will be found less brittle and more easily studied.

a. What is the outline shape of the Lima bean?
b. Is it flattened?
c. In which direction?
d. Do you find the hilum, the point where the stalk called the funiculus attached the bean to the pod?
e. What is the shape of the hilum?
f. Do you find a small opening near one end of the hilum?
g. This is the micropyle. What is its function?
h. Draw a bean, side view, enlarged.
i. Draw an edge view to show either the funiculus or the hilum, and the micropyle.
j. What is a pod called?
k. Is it an ovary or an ovule?
l. What is the bean seed?

2. With a knife carefully split a bean seed. Remember where the micropyle is located.

a. Do you distinguish the seed coat? It is called the *testa.*
b. Is it thick or thin?
c. Is it tough?
d. Of what advantage is it?
e. What is the function of the seed coat?

3. Everything inside the testa, or seed coat, in a bean or any other legume, is the embryo. The two large halves are called the *colyledons*, or *seed leaves.*

a. Are the cotyledons of equal size?
b. Do you find the *plumule*, two delicate little leaves which are inclosed between the cotyledons? When the cotyledons are broken apart, the plumule remains attached to one or the other.
c. Note below the plumule the *radicle*, the part that develops the root. What shape is it?
d. How long is it compared with the plumule?
e. Is the tip of the radicle near the micropyle or on the opposite side from it?
f. Explain why this is so.
g. Do you think water might enter through the micropyle?
h. Draw the cotyledon with the plumule and radicle attached, showing the seed coat which surrounds it.
i. Is there food in the cotyledons?
j. Where is the food located which supplies the young plant as it develops?

Exercise 70. A Study of a Bean Seedling

Material needed. Lima-bean seeds.

1. Each student should plant in soil three or four bean seeds for his own use. This may be done in a small wooden box or in small flowerpots. If the beans are soaked overnight before they are planted, they will germinate more rapidly. Observe the beans as they are coming through the ground.

a. Are they curved?
b. Explain what you see. (It may be necessary to make observations from time to time for several days.)
c. What parts come through the soil first?
d. What is the curved portion called?
e. What becomes of the hypocotyl?
f. What happens to the cotyledons?
g. Do they change color?
h. If so, what color do they assume?
i. Do you think that the cotyledons manufacture food?
j. Does green tissue usually manufacture food? Explain how green chlorophyll can develop in cotyledons.
k. What becomes of the food in the cotyledons?

2. Study a seed in which the plumule is well developed.

a. Describe the appearance of the cotyledons. Are they plump or wrinkled?
b. Do you think they have lost food to the growing plant?
c. How do the larger seedlings get food?
d. What happens to the cotyledons?
e. Draw a series of bean seedlings, showing the seedling (1) as it emerges from the ground, (2) as it begins to straighten, (3) as it develops the plumule, and (4) as it loses the cotyledons.
f. Is the bean a monocotyledon or a dicotyledon?
g. How do you know?
h. Can you name an example of the class to which you say the bean does not belong?

Exercise 71. A Study of the Corn Seed

Material needed. Ears of corn.

1. Study the ear.

a. What is the central part called?
b. Is it a receptacle?
c. Note the concave part of the grain. Which way does it face on the ear?
d. Are the grains in rows?
e. Do you see any "silks"?

f. What are they? That is, to which of the parts distinguished in botany do they belong?

g. Examine carefully and see if you can find where they attach to the grain. The point where they attach is called the *silk scar.*

h. If the silk is the style and the stigma of the pistil, what part do you think the grain is? Is it an ovary or an ovule?

i. The seed of corn is called a *caryopsis,* or *grain.* Does this help you to answer the preceding question? If not, find the answer in the text.

2. Soak enough corn for the class several hours before using. Study a single grain of corn carefully, using that previously soaked.

a. Why is the top of the grain sunken in field varieties? Remember that the grain is full of starch and water in the fall, when it matures.

b. Is it round or flat?

c. The concave place on the face of the grain is called the *scutellum.* Is it at the top of the grain or at the bottom?

d. Is it narrower at the top or wider?

e. Is the silk scar on the same side as the scutellum, or on the opposite side?

f. Is it above or below?

g. Draw a face view of a grain of corn, showing the scutellum and the silk scar.

h. Draw a side view.

3. Cut a grain of corn through the narrow way from face to back so as to divide the scutellum into halves. Examine the cut edges.

a. Do you see the scutellum in edge view?

b. Does it extend completely to the back of the grain?

c. All the rest of the grain inside the seed coat consists of endosperm. That which is white and floury is called *starchy endosperm*; that which is glazed in appearance is called *horny endosperm.* What percentage of the endosperm does each constitute? Can you prove it to be starch? How? Test it and record your results.

4. Examine the edge of the scutellum for the small embryo.

a. Do you find the embryo?
b. Describe it.
c. The part pointing downward is the radicle; the upper portion is the plumule. Do you find them?
d. Draw a view of the cut surface, showing all parts, including the embryo. Label all parts.

Write a page on seeds, discussing the bean and corn in particular.

Exercise 72. A Study of Corn Seedlings

Material needed. Grains of corn.

1. Each student should be required to plant several grains of corn in soil in small boxes or flowerpots. Watch them carefully, supplying water as needed. Observe them as they emerge.

a. Is the plumule covered with a thin cap?
b. What would be the value of this to a tender plant growing through soil?
c. What happens to the cap in those plants where it is not disturbed?
d. Do two leaves spread out at once or do they appear one at a time?
e. Draw a corn plant as it emerges, showing the cap that covers it.
f. Draw larger stages of the seedlings, showing a series. Include the roots.

Exercise 73. A Study of Absorption by Seed Coats

Materials needed. Honey-locust seeds or black-locust seeds; a knife or file; blotting-paper; dishes, with glass to cover. This study with the seeds is designed to show the imperviousness of seed coats to water. Locust seeds are valuable because of their extreme hardness.

1. Carefully examine the seeds of the locust.

a. Try to bite a seed. Is it hard or soft?
b. How are the seeds borne on the tree?
c. What is such a fruit called?
d. What is one important value of legumes?
e. Do you think the locust tree may fix nitrogen, as does clover or alfalfa?
f. Why do you think so?
g. Draw a single seed.
h. What color is it?

2. Select ten seeds of uniform size. Scratch the seed coat of five of them with a sharp knife. Leave the others as you have taken them from the pod. Place the five with the injured seed coats on a moistened blotter at one side of a dish, and place the five with uninjured seed coats near the other side of the dish. Cover with a well-soaked blotter. It is important that the blotters be very moist. Cover with a glass plate and set aside at room temperature. Examine in twenty-four hours, again in forty-eight hours, and twenty-four hours later, if necessary.

a. Do you see any difference in the two lots of seeds?
b. Explain the result.
c. To what do you believe it is due?
d. Draw a seed of each lot to contrast. Label each properly.
e. Do you think there would be any advantage in scratching the coats of such seeds before planting? What advantage?
f. Often sweet clover, alfalfa, and red clover are scarified; that is, run through a mill, which scratches the seeds. What value do you see in this?
g. Do you think the trouble necessary to do this is worth while to a farmer?
h. If you were discussing this with a farmer, would you recommend such a procedure?

3. Write a paragraph, discussing this experiment.

Exercise 74. A Study of Scarification and Germination in Legumes

Material needed. Alfalfa, red clover, or sweet clover seed.

1. If the teacher desires, the following experiment may be made. It will be found highly desirable for agricultural students. First, secure some alfalfa, red clover, or sweet clover heads directly from a field and hull the seed by hand. In this way there is no possibility of scarifying. A large number of heads should be used and the seeds put together so that there will be a uniform lot of seed.

Second, secure a lot of seed which has been threshed by machine, from a machine directly or from a seed store.

Third, take half of the machine-threshed seed and rub it carefully over a sharp file. If possible all the seed in the three lots should be from the same field. Place a hundred seeds of each lot in dishes to germinate as directed in Exercise 73 and record the results. Select uniform, round, plump seeds for the experiments. Write a page on the value of scarification of legume seeds, giving your results. Answer the following questions:

a. Is there a difference between the germination of the seed hulled by hand and that hulled by the threshing machine?

b. Do you think a thresher scarifies some seed? How might it do this?

c. If so, about what percentage?

d. Is this sufficient scarification, or should a scarifier be used also?

e. What difference of percentage, if any, exists between the germination of the machine-threshed seed when scarified and when not scarified?

f. What difference of percentage did you find between hand-hulled seed and scarified seed?

g. Account for the difference.

Exercise 75. A Study of the Need of Water for Germination

Materials needed. Grains of corn, wheat, and rice; dishes; blotters. In most regions the rice will need to be purchased from a seed house. If not available, it may have to be omitted.

1. Secure six flat-bottomed dishes large enough to accommodate fifty grains of corn. Number the dishes from 1 to 6. Place a blotter in each dish. Thoroughly moisten the blotters in dishes 1, 3, and 5; leave the other three dry. Place fifty grains of corn in dish 1 and fifty in dish 2; fifty grains of wheat in dish 3 and fifty in dish 4; fifty grains of rice in dish 5 and fifty in dish 6. Cover the grains in the dishes containing the moist blotters with a second moist blotter. Those in dishes 2, 4, and 6 are to be covered with dry blotters. Close each dish with a glass plate and set aside in a warm place. Examine each dish at the end of twenty-four, forty-eight, and sixty-four hours, and at like intervals thereafter, if necessary.

a. Do any of the seeds show signs of germination?
b. What leads you to your belief?
c. Are there differences in size between those seeds which have moisture supplied and those which have not?
d. Do you think water is absolutely necessary for seed germination?
e. Can you explain how seeds take up moisture?
f. What is the effect of absorbing water on the seed? (See Pool and Evans's "First Course in Botany.")

2. The following part of the exercise is made optional with the teacher. It is recommended for agricultural students as a demonstration of the great affinity which the seed has for water. Even in the presence of very small amounts the seed is usually activated.

Secure samples of soil which contain varying amounts of water. One should be very dry, a second only slightly

more moist, and so graded to those which are very wet. The series should include five or six samples all of the same type of soil. It may be necessary to dry the samples to the desired point by exposure or by heating gently. Be sure the samples form a series. Plant several kernels of corn in each sample of soil and cover with a glass plate to prevent evaporation. At the end of four or five days examine the kernels.

a. Are they all showing signs of germination?
b. If not, which are not?
c. Is there enough moisture in the dry soil to supply the kernels with sufficient moisture to germinate?
d. Will corn germinate in soil which seems dry?
e. What practical value do you see in such a lesson?
f. Should you advise planting corn in dry soil to await rain for growing?
g. Explain your answer carefully, taking into consideration the fact that the seeds may germinate and that rain may not come for some time.

Exercise 76. A Study of Oxygen and its Necessity in Germination

Materials needed. Corn; beans; rice; six bottles; blotters; cotton.

1. Label the bottles from 1 to 6. Place a small piece of blotter in the bottom of bottles 1, 3, and 5 or place moistened cotton in these bottles and place on it the seeds to be germinated. In bottle 1 place ten grains of corn, in bottle 3 ten bean seeds, and in bottle 5 ten grains of rice. Stopper each bottle loosely with cotton.

a. Can air pass through the cotton?
b. What are the main constituents of air?
c. Is there air in these three bottles?
d. Is there oxygen?
e. Can the oxygen reach the seeds?
f. Place the bottles aside in a warm place and watch daily for any changes.

2. In bottles 2, 4, and 6 place seeds as follows: In bottle 2 place ten grains of corn, in bottle 4 ten bean seeds, and in bottle 6 ten grains of rice. Boil some water to drive off any air which it contains. Allow it to cool to room temperature without stirring. Now fill bottles 2, 4, and 6 by pouring the water gently into them so that it flows down the side. Fill full of water, then stopper tightly with a cork. Set aside with the other bottles of the experiment. Observe from time to time.

a. Why will the boiling of water drive off air?
b. Will the oxygen which is not in combination be driven off?
c. Why cover the seeds with this water?
d. Why pour it gently into the bottles?
e. Is all the air driven out of the bottle when it is filled with water? Is all the free oxygen?
f. Do you think any oxygen is available for the seeds so treated?

3. When the seeds have remained until the beans and corn in bottles 1 and 3 are well germinated, examine all carefully.

a. Did the corn, beans, and rice germinate in bottles 1, 3, and 5?
b. If not, which did not?
c. Did they all germinate equally well? (NOTE. Rice does not usually require oxygen for germination.)
d. Did you observe any difference in the seeds?
e. Record your observations.
f. Examine the seeds in bottles 2, 4, and 6. Have all germinated?
g. Have any germinated? Rice usually will germinate under such conditions. Examine it carefully.
h. Is oxygen present?
i. What do you conclude concerning a seed which will germinate under these conditions?
j. Do you think that this is the usual thing?
k. What has happened to the other seeds?
l. What do you conclude concerning their needs for germination?

4. Write a paragraph, giving your conclusions relative to the need of oxygen for germination in different seeds.

Exercise 77. A Study of the Viability of Seeds

Materials needed. Let each student secure about twenty-five kernels of corn from different ears (these may be procured at home or they may be furnished by the teacher); culture dishes or other convenient dishes in which to germinate the seed; blotters. One hundred grains may be used.

1. Place a blotter in the dish and moisten well with water. Place twenty-five kernels of corn in neat rows across the dish, spacing as widely as room permits. Cover with a second blotter which has been thoroughly soaked in water. Cover with a glass plate and set aside in a warm place. Examine after three days.

a. Has the corn begun to germinate?
b. How many kernels?
c. Do those that have not germinated appear to be alive?
d. Does the root or the shoot appear first?

2. Replace the blotter and, if dry, supply sufficient moisture to keep the plants growing. Examine again about two days later. Many times kernels will sprout and then die. Often a root will appear and not a shoot. Sometimes shoots will be developed and not roots.

a. Do you find any which have sprouted and then died?
b. If so, can you explain why?
c. Do you see any molds growing on the grains?
d. Might this not be responsible for the death of seedlings?
e. Do you find any kernels which have failed to develop either root or shoot?
f. Were there any kernels which were dead and did not respond at all?
g. Figure out the percentage of germination.
h. Do you consider this a high or a low test?
i. Would it be profitable to plant such seed?

j. Figuring ten rows to an acre and the hills three feet six inches apart, how many stalks of corn should there be on an acre if each hill has three stalks?

k. If the corn planted on the acre showed the percentage of germination which you have found, how many stalks would there be?

l. How many hills would be missing per acre where such seed was used, counting three stalks to a hill?

m. If each stalk produced an ear, and one hundred and twenty ears are necessary to make a bushel, how many bushels would be lost by planting this seed?

FIG. 29. Samara of *Acer saccharum* (sugar maple)

n. At the market price per bushel, what would be the loss?

o. What is good seed corn worth which will germinate 100 per cent?

p. Would the loss pay for good seed? Consider a bushel of seed sufficient to plant eight acres.

q. Do you think it would be worth while to secure good seed?

3. Write a paragraph, telling how one should go about testing several bushels of seed corn in a competent manner.

Exercise 78. A Study of Fruits

The study of fruits may include so many types that the outline given below is only suggestive of what may be done. The student should be required to read the subject in Pool and Evans's "First Course in Botany." This gives a concise discussion of various types of fruits which may be studied. For convenience they should be studied as (1) dry fruits and (2) fleshy fruits. Under dry fruits may be taken up the dehiscent and indehiscent forms. Most of the materials necessary can be collected in any community. Those which cannot, may be omitted or substitutions made. For convenience a list of dry and fleshy fruits are included under "Materials needed." Many can be bought in the

market, and others will be found available in nearly any garden. Most of those listed below are common.

Materials needed.

- Dry fruits
  - Dehiscent
    - Follicle: larkspur
    - Legume: bean
    - Capsule: iris, poppy
    - Silique: honesty, Draba, shepherd's-purse, or mustard
    - Pyxidium: plantain, purslane
  - Indehiscent
    - Caryopsis, or grain: wheat, corn
    - Achene: sunflower
    - Nut: acorn
    - Samara, or key: maple, box elder
    - Schizocarp: mallow, hollyhock
- Fleshy fruits
  - Berry: tomato, currant
  - Modified berry: orange, lemon
  - Drupe: peach, plum
  - Pome: apple, pear
  - Pepo: watermelon, cucumber
  - Aggregate: raspberry, blackberry
  - Accessory: strawberry
  - Multiple: pineapple, mulberry.

1. The discussion here will be such as might be used for a poppy fruit. It may be utilized with modification for all others.

a. Is this fruit dry or fleshy?
b. Is it dehiscent or indehiscent?
c. Explain your answer.
d. How does it differ from other fruits?
e. How are the seeds distributed?
f. Are the seeds small or large? smooth or rough?
g. Are there a large or small number of fruits on a plant?
h. Draw such a fruit, side view.
i. Split it through the center from top to bottom, and draw.
j. How many chambers, or locules, does it have?
k. Find out, if possible, how the seeds are attached.

2. In a study of fleshy fruits answer the following questions:

a. What is the approximate shape of the fruit?
b. What flower parts are a part of the fruit?
c. What is its color?
d. Is the seed large or small?
e. Is there one seed or more than one?
f. Draw the whole fruit.
g. Cut a cross or longitudinal section of a fruit as directed by the teacher and draw the cut surface to show the parts.

Exercise 79. A Study of the Modes of Dispersion of Seeds

If all seeds from a plant were to fall upon the ground near it and grow, the competition among the seedlings would be so great that many would die. The continuation of such a condition would result in the elimination of many plants. Nature has provided for the wide distribution of plants by many means. Various hairs, hooks, plumes, spines, wings, and stickers of many forms provide the means for their being carried by animals, by wind, by water, and by man into new areas. In some plants the bursting of the seed receptacle provides a means of throwing the seeds some distance away from the parent plant. Other plant seeds are distributed through their being eaten with the fruit and thus carried long distances. This is especially true of fruits eaten during the migrating season of birds.

Materials needed. Any winged, plumed, hooked, or sticky seeds or fruits, including any sorts that are known to float on the air or to give annoyance by sticking to clothes; any fruits which, when disturbed by a passing animal, burst with violence enough to throw the seed into the animal's fur; dead tumbleweeds of any kind; complete stalks, with fruits on them, of any plant whose stock, when disturbed by a passing animal, swings elastically and slings the uppermost seeds into the departing animal's fur.

1. Examine a dandelion which is setting seed. The long hollow stem-like structure is called the *scape*. It has remarkable powers of growth, developing to the length of a foot or more in a day or two after the seeds ripen. It bears the seed on its upper end.

a. What is the shape of the ripened head?
b. To what is this due?
c. Draw a matured head about natural size.
d. What is the function of the green bracts?

FIG. 30. A branch of a cocklebur with several of the spiny fruits attached

2. Remove a single seed with its umbrella-like equipment.

a. Describe the umbrella.
b. Will it lie upon the table without trouble or are slight air currents sufficient to blow it away?
c. How is it oriented in floating through the air?
d. Can you see any advantage of the long scape in this plant?
e. What would be the result if the seeds were borne on as short a scape as the immature flowers?
f. Do you think this is a successful means of distribution in the dandelion?
g. Why do you believe your answer to be correct?

3. Study a seed from the cocklebur.

a. What means of distribution has it?
b. Do you think it is distributed by the wind?
c. Do you think it might roll a long distance on crusted snow?

d. Would you consider wind as a factor in cocklebur distribution?

e. In what way is it well equipped to be distributed by animals?

f. How might it be dropped after being carried some distance by the animal? Is there any adjustment in the height and shape of the cocklebur plant which may be an aid in distribution?

g. Do you think it might float in a stream?

h. See whether the bur will float or sink in water.

i. What evidence do you have which would indicate that cockleburs do float in streams?

j. Cut a cocklebur open. How many seeds does it have?

k. Of what advantage is this?

l. Draw a cocklebur seed. The two horns at the upper end are the old stigmas. Label the parts.

4. Study an acorn that is the type of nut borne by the oak.

a. How would you suggest they may be distributed to points some distance from the tree where they have grown?

b. If all the acorns fell directly to the ground beneath a tree, do you think they would remain there?

c. How would you suggest they might be scattered? List all the ways of which you can think.

d. Which do you think would be distributed more widely and more rapidly, an acorn or a dandelion? a dandelion or a cocklebur?

e. Draw an acorn. Label all parts.

5. The fruits of raspberries, honeysuckles, currants, gooseberries, and small fleshy fruits of the same sort are distributed largely by birds. The seeds are eaten but not digested. In this way they may be carried some distance.

a. Do you think seed may be carried far by birds; that is, do birds remain in the community or do they fly long distances each day?

b. If birds remain about a community, especially when nesting, are there other times when they may travel long distances?

c. Explain when you believe they travel.
d. Which do you think might be distributed farther, a dandelion or a raspberry? Remember that raspberries are gone when birds are migrating in late fall.
e. Do you think of any fruits that are ripe in late fall when birds are migrating? Make a list of such fruits.

6. Secure some of the seed pods of a violet which grows close to or within the ground. Pull a number and place in a small pasteboard box near a radiator. During the course of a few hours the pods will dry sufficiently to burst with some force and throw the seeds against the sides of the box. Observe and see whether you can discover how they break.

a. Do you observe that the pods rupture with force?
b. If you do not hear the pods bursting, look into the box at the end of the day. Do you find that the seeds have been dispersed?
c. Is the rupture of the pod in this fashion an advantage?
d. Explain your answer, giving reasons.
e. What name is applied to such forcible distribution of seeds?

7. Examples of distribution by wind, by water, by animals, and by propulsion have been discussed. With these as a suggestion, study any other seeds or fruits which may be available.

8. Write a page or more on the distribution of seeds.

Exercise 80. A Study of How Environment Influences the Plant

1. For this study it will be necessary to make a trip into convenient fields or gardens. If it is desired and time permits, plantings may be made in various situations with good opportunities for study.

Select a convenient low place in a grain field and study the condition of the grain on both the high land and the low land. The conditions as to the amount of moisture present must be noted. Too much water, too little water, and the optimum amount of water all constitute different ecological conditions which make the environment.

a. If too much water is present in the low land, what is the result upon the vegetation?
b. Will the grain on the high land likewise suffer?
c. Will plants of other kinds grow in low land which has standing water?
d. Can you name some?
e. Do you conclude that the grain or such plants as you have named are the more tolerant of water?
f. Would you say that standing water constitutes a favorable environment for such plants? for grain?
g. Is standing water a favorable environment for farm crops such as corn, wheat, oats, rye, barley, and flax?
h. List all weeds you find in such a field.

2. Suppose that the season is a very dry one in the region where the low land you are studying is located:

a. Which environment will be the more favorable for grain, the low land or the high land?
b. Why do you believe so?

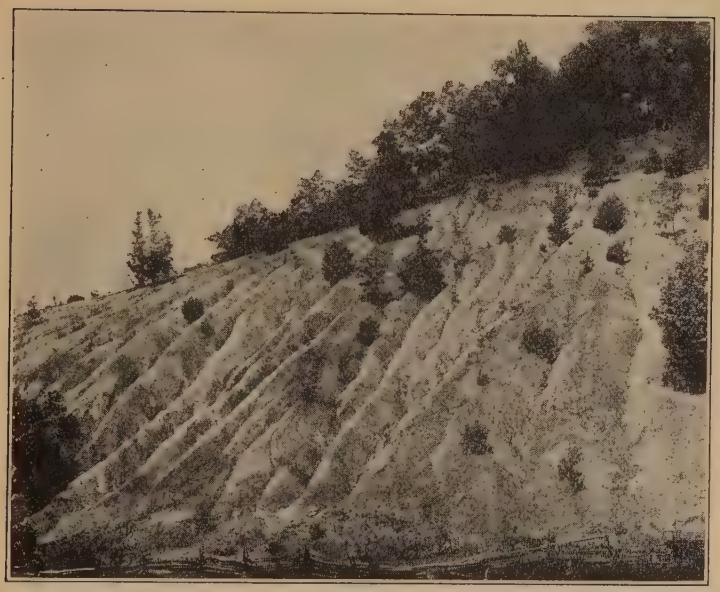

FIG. 31. Deep gullies eroded in a hillside in western North Carolina after forest has been removed

c. What will be the conditions as to moisture?
d. Will some species of weeds develop in soil where it is too dry for grains?
e. Give their names if you find some.
f. Do you find these same weeds growing elsewhere? Where?

3. Suppose the conditions of moisture are optimum in low lands and high lands:

a. What will be the condition of grains in each environment?
b. Which will be the better? Why?
c. Do nutrient salts of various kinds leach through the soils to low lands?
d. Is this beneficial or detrimental to the low lands? to the high lands?
e. Can you suggest how erosion and leaching can be prevented?
f. Which would be the more effective, grass or trees?

Exercise 81. A Study of Water as a Factor Influencing the Environment

1. Select a large pond for study (Fig. 32). If it is in an ungrazed area, it will be much better suited for the purpose of this study. Grazed areas are often badly disturbed.

FIG. 32. A pond showing vegetation, especially the water lily

a. Do you find plants growing in the water?
b. What kinds of plants are present?
c. Are they water-loving plants?
d. Would you conclude that they were successful?
e. Do you think a water plant such as those that grow under water would be able to grow on land?
f. Are bulrushes successful out of water?
g. What happens to them when the water disappears from a pond?
h. Do you find plants which grow partly in the water and partly out of it?
i. How does erosion affect the plant (Figs. 31 and 33)?

2. Observe carefully whether or not there are zones of vegetation about the pond. Often it is found that there are broad belts of vegetation extending back from the edge of a pond, one succeeding another. The first may be only a few feet wide; others may be from fifteen to twenty feet or more wide. Again, definite zoning of vegetation may be

FIG. 33. Results of rapid erosion in a forest

Observe how trees are often washed out

absent. Look for rushes and waterlilies in and about the water's edge; cat-tail flags, reed bent grass, and other shore grasses just back of the water on wet shores; creeping plants with runners or stolons on sandy shores; and other plants under other conditions of the environment.

a. Name all the plants that you can find in such situations.

b. Do you find that plants are distributed according to their adaptability to different environments?

c. Would you expect to find water or shore plants in dry situations?
d. Explain your answer definitely.
e. Would you expect blue grass to grow well on the shore of a pond? Why?

Exercise 82. A Study of Light as an Environmental Factor

Material needed. Varying conditions of light as in forests, under shade trees, on the north side of houses.

1. We have seen how water influences the environment and eliminates certain plants and augments the growth of others. Water, then, can be said to be a very definite factor in the environment. Likewise light has been found to influence plants. In forests only certain plants can grow in the shade of the trees. This is because of lack of light, only diffuse light being able to reach the forest floor. Ferns are found to grow abundantly in such a situation. Study the vegetation beneath the trees in a forest if you have opportunity. If not, a small timber or wood lot will be worth while.

a. Do you think that ferns require much light?
b. Can you suggest why people who dig ferns in a thickly wooded area and plant them in the open yard have trouble in making them grow?
c. What would you suggest as to light in transplanting ferns?
d. Where are such conditions most likely to be found about the home?
e. Do you think too much light is detrimental to ferns recently removed from a forest? Is too little water detrimental? Do you think the amount of water in the air is important to ferns?
f. How do you explain the case of the Boston fern which lives well in bright light?
g. Does it do better in subdued light?
h. Do you think a plant may gradually become adjusted to greater degrees of light?
i. What other plants may be found associated with ferns in deep woods? Make a list of them.

2. Study the lawn in the dense shade of a clump of several trees.

a. Do you note a difference between the grass which is shaded and that on the adjacent lawn which is not shaded?
b. Under which condition is the stand the better?
c. To what do you think this may be due?
d. May light play a part?
e. Do you think moisture might?
f. Do other plants, especially weeds, replace the grass where the stand is thin? Why?

3. Study, if possible, a field of grain which passes under the shade of trees. Corn or small grains will show the effects of shading very well.

a. Does the grain in the shade of trees grow as well as that which is not shaded?
b. Is there a striking difference in height?
c. Is there a lack of vigor?
d. How will yields from such conditions compare?
e. Do you feel from your observations that light plays a prominent part in different environments?

Exercise 83. A Study of Heat as a Factor which Influences the Environment

Materials needed. Two boxes, 3 inches deep and about 1 foot by 2 feet; corn; soil.

1. Place an inch of moist soil in the bottom of each box. Set one box in a warm place overnight; place the other in a cold situation overnight. The temperature should be less than 50° F. but not lower than freezing.

Plant 100 kernels of corn in each box. Cover the planted corn with two inches of moist soil which has been stored at the same temperature as the box into which it is put. Keep the soil uniformly moistened until germination results in one box. Do not allow the temperatures to change during the experiment.

a. In which box did the corn first make its appearance?
b. Can you account for this?
c. Could it possibly be moisture which would cause the difference?
d. Does light influence germination?
e. What was the percentage of germination in the box which first produced seedlings?
f. Unearth the other grains. Have they sprouted?
g. If so, what percentage?
h. How do you account for seasonal planting of grains?
i. When conditions are correct for the germination of certain seeds in Illinois, are conditions right for the same kind of seeds in North Dakota?
j. If temperature will influence seed germination, do you think it may influence the growing plant?
k. Which do you think may be the limiting factor or factors — temperature, moisture, or light — in growing cotton? corn? wheat?
l. Do you think of any other factors that may influence the environment?

2. Write a report, giving the main features concerning the effects of light, moisture, and temperature upon plants whether as seeds, as seedlings, or at maturity.

WEEDS

The best study of weeds requires taking the class into the field. Various annual weeds may be seen along any roadside or side street. Many will be found in gardens and fields. An occasional trip into such areas should be profitable. Occasionally perennial weeds with roots and rootstocks that live over will be readily discovered. For these it is best, however, to locate certain fields which contain them through inquiry and go directly to them without loss of time. The students will no doubt know of such places.

Exercise 84. Inspection Trip of Garden, Fields, and Roadsides for Weeds

1. A field trip to be of value must be seriously undertaken. If it is merely made into a pleasure jaunt, it is not generally worth while. There will of necessity be occasions when little of importance is to be observed. It is during such lulls that visiting among students should occur. When something of importance is being discussed by the teacher, it is only courteous to remain quiet and listen. The trip should generally start the moment one leaves the school, for many weeds are widely distributed.

Weeds such as the lady's-thumb, knotweed, plantain, dandelion, ragweed, foxtail, and dock are found in many lawns.

Observe the weeds along the sidewalks. Ordinarily they are much smaller and less well developed than those in gardens where there is less interference from traffic. Note how luxuriously some weeds grow in rich well-watered garden soil or in the fields.

If possible, study such weeds as the Russian thistle, tumble mustard, cocklebur, Spanish needle, and sticktight. These offer mechanical means for fastening themselves upon animals and in clothing. Note the arrangement of the seeds by which they are placed in a favorable position for becoming attached to passing animals which touch them.

FIG. 34. Russian thistles which have broken off at the ground level and have rolled along, dropping their seeds, until stopped by a fence

Study the Canada thistle, common thistle, milkweeds, Russian thistle (Fig. 34), and other weeds with plumed seeds for wind distribution. Do you think they are successfully distributed?

Answer any questions which may be required of you; then write a detailed report of the trip you have taken. The report should include the names of weeds found and identified, where they were found growing, their means of dispersal, their success as weeds, why they are successful, and any other information that occurs to you. If you will read the chapter on weeds in Pool and Evans's "First Course

in Botany," many ideas may suggest themselves to you as to why weeds are successful.

It will be found worth while to visit several localities, possibly spending two or three laboratory periods on the subject. Any weeds not identified should be sent to your state agricultural experiment station for identification. The students should be encouraged to do this themselves. When the specimens are gathered, it is always well to include flowers or seeds, or both. Press the specimens between blotters, which should be weighted down. Change the blotters every day for about a week or until the specimens are dry and well pressed. Label all specimens of the same kind with the same number. Send in a specimen for identification. The party responding can identify it by number, and you may refer to your numbered specimen for identification. The plant should then be labeled by name.

Exercise 85. A Study of the Root Types in Weeds

1. With a shovel dig up the root systems of the several species of weeds studied in Exercise 84. List all the specimens and answer the following questions for each species. This exercise may be answered by making a table in the following manner:

A Study of the Roots of Common Weeds

Kind of Weed	Taproot		Fibrous Roots	Underground Roots	Underground Rootstocks	Length of Roots	Height of Plants	Other Remarks
	Woody	Fleshy						

a. How do you distinguish a woody and a fleshy taproot?
b. Do you think fibrous roots are usually deep roots?
c. Do they obtain their water and nutrient salts near the surface or from a deeper source?

d. Can you explain how a grassland may prevent trees from invading it?

e. Explain your ideas, remembering that all trees pass through seedling stages — a delicate stage in their life history — and must obtain water from surface supplies.

f. How do you distinguish an underground root from an underground stem or a rootstock?

g. Has the length of stem any relation to the length of root? Explain your answer carefully.

h. Has the shape of stem any relation to the shape of root? Explain your answer.

i. Account for the rapid recovery of grass, which has been injured by drought, after a shower of rain.

j. Do deep roots receive much water from occasional showers?

Exercise 86. A Study of Delayed Germination in Seeds

Materials needed. Foxtail seeds; wild oats seeds; ragweed seeds; thistle seeds; any other weed seeds you may find to be important in your community.

1. If possible, pick these seeds from the plants in the fall and endeavor to germinate them at once. If the study does not occur until spring, the seeds should be gathered in the fall by the teacher and kept in the laboratory until the class meets. Germinate the seeds between blotters moistened with water. This experiment must be done before February to obtain the best results. Answer the following questions for each kind of seed:

a. Have all the seeds germinated well at the end of a week?

b. What percentage has germinated?

c. Do you think germination has been delayed?

d. Of what value is this to the seed? to this species of plant?

e. Do you think many seeds show delayed dormancy?

Germination should be tried at intervals of a month until the seeds germinate or until May. Record your results each time on the same page. Arrange in tabular form.

Exercise 87. A Study of Weed Seeds in Grain

It is reported that 10,000 cars of weed seeds and dirt are shipped each year to the Minneapolis market by farmers. Of course the freight is paid on this worthless material. Likewise the farmer suffers dockage on his grain.

a. Do you think it would pay to remedy this situation?
b. How would you go about it?

Materials needed. Various grains, such as wheat, oats, rye, barley, and flax, direct from the thresher. If the grain is secured from an elevator, be sure it has not been recleaned.

1. Weigh out 100-gram samples of the uncleaned grain. Before doing this satisfy yourself that the grain is uniformly mixed. Very often it will be found that heavier seeds will work to the bottom and lighter ones to the top. The bag containing the grain should be up-ended several times, or if it seems desirable the grain should be poured into a large measure and stirred well. Place upon a clean table the sample that you have weighed. Now proceed to separate the grain from the chaff, weeds, dirt, and foreign material. After separating, weigh the grain.

a. How many grams of foreign seeds and dirt, commonly known as dockage, are there?
b. What percentage of the whole is this?
c. How many bushels of dockage would there be in a 1400-bushel car of this grain?
d. If it costs $150 to ship a carload of this grain 250 miles, what percentage is being paid on worthless material?
e. How many dollars is this?
f. There is shipped to the terminal market at Minneapolis each year approximately 10,000 cars of weed seeds, dirt, and foreign materials in cereal grains alone. If the average freight rate is the same as in question *d*, what is the bill the farmers are paying in extra freight on worthless material?
g. Can you suggest a method of eliminating this expense?

h. Does grain with these foreign materials sell for the same price as clean grain?

i. Suppose that uncleaned grain is docked 2 cents per bushel in the terminal market. Is this the only loss to the farmer?

j. What would be the total loss on a car of grain figuring both freight and dockage on the basis of the sample which you graded? Consider the distance as 250 miles.

2. For agricultural students and others grain should be brought from their own bins as it seems desirable, and the percentage of foreign materials calculated. Shelled corn direct from the sheller may be used. In this calculation cracked grains and pieces of grains are to be counted with the grain. Cobs, rotten kernels, weed seeds, and dirt are counted as dockage. Answer questions for each grain used.

a. What is the percentage of weed seeds and refuse?

b. What weeds are most prevalent? If you are unable to identify the weed seeds, send them to your state agricultural experiment station for identification. Put a number in each packet of seeds and retain a sample under the same number for reference when the identification is returned. Place only one kind of seed in a packet.

c. How many bushels of each kind of grain were sold from your farm during the past season?

d. What percentage did you lose by dockage? How many bushels?

e. How many bushels are shipped in the average car? Inquire of your freight agent.

f. What is your terminal market?

g. Ascertain also the freight rate on a car of each kind of grain to the terminal market. How much is this?

h. How many dollars did it cost to ship your grain?

i. How many dollars of this was for freight on weed seed and other dockage?

3. Write a page on the subject of weed seeds and foreign materials in grains.

4. The teacher may add any other materials which seem of value in this study, including written reports.

Exercise 88. The Value of Scientific Names for Plants

Classification of plants is necessary that they may be clearly distinguished. To refer to plants by a common name is to distinguish them only in the community in which they are well known. Since plants are of universal interest, it is necessary to distinguish them for people of all nations. It is for this reason that Latin and Greek names are used, for these languages are not developing and are available to all people. Plants named in Chinese, Russian, or Japanese would be known to only a few people. Read the chapter on Classification of Plants in Pool and Evans's "First Course in Botany." Now write a two-page report on "The Value of Scientific Names in the Classification of Plants." If other material on the subject is available, make use of it.

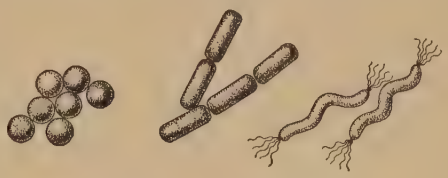

FIG. 35. Types of bacteria

The coccus is spherical, the bacillus is capsule-shaped, and the spirillum is spiral

BACTERIA

Bacteria (Fig. 35) have been studied with relation to the fixation of nitrogen in soil. The student should remember that the subject of bacteria is a large one and constitutes in itself a science called *bacteriology*.

Kinds of bacteria. There are three general types of bacteria, namely, those which are rod-shaped, the approximate

shape of a quinine capsule; spherical-shaped, the shape of a basket ball; and the spiral-shaped, the shape of a corkscrew. All these types are plants despite the popular opinion that they are animals. A certain rod-shaped bacterium causes typhoid fever; a spherical form causes the formation of pus; and the spirillum form is responsible for diphtheria and some other diseases that are common to man.

The size of bacteria. Bacteria are very small. It is hardly worth while to say how large they are, for our imaginations can scarcely appreciate their minuteness. In general it would take from 1200 to 1800 bacteria placed end to end to extend across the head of a pin. The point of a pin dipped lightly into a culture would actually pick up thousands of these tiny plants.

The structure of a bacterium. Each bacterium is surrounded by a cell wall which incloses a minute speck of protoplasm. A nucleus has never been demonstrated in bacteria.

Are bacteria harmful? Many bacteria have been positively proved to be harmful to man, others to be harmful to plants, and still others to lower animals. The number that are harmful, however, is much less than those which are of value. Probably no more than two hundred can be actually classified as harmful, but many thousands are known to be beneficial.

Microörganisms are essential in our soils. In just what ways they are of value is not always clear. They play a prominent rôle in the industries, arts, and sciences. They are essential for the making of cheese, the making of butter, and the retting of flax, hemp, and jute. They have played an important rôle in the making of indigo and many other organic compounds. They are of immense importance in making bread, vinegar, cider, and numerous other products in daily use. Their importance no doubt far outweighs their harmful effects. If it were not for bacteria, no decay could

occur and the world might soon become clogged with useless and even harmful materials. Their most harmful effect comes from the numerous pathogenic forms which cause disease, but man has made great strides in the lessening of the seriousness of these.

Reproduction in bacteria. Bacteria reproduce by division. A single bacterium divides into two equal parts, each cell increasing in size to that of the parent cell. When fully matured each of these individuals gives rise to two new cells, so that four new individuals have been formed from the original one. Later 8, 16, 32, 64, and so on are formed in rapid succession. A bacterium may mature and divide during the course of an hour, so that at the end of the first hour there are 2, at the end of the second hour there are 4; at the end of the third hour 8; and so on. How many might be formed under favorable conditions in the course of twenty-four hours? The speed with which they increase is unbelievable, and were it not for unfavorable conditions, all other living things would be crowded out. It is only unfavorable environment that holds them in check.

Exercise 89. A Study of Bacteria

Materials needed. Dry bean seeds; shallow dish with cover; compound microscope.

1. Place a handful of beans in a dish and cover with water. Allow the dish to stand in a warm place for two days. Secure a drop of the solution at the end of this time and place it upon a slide. Mount under a cover glass and examine with the high power of the compound microscope. If the light is carefully adjusted so that not too much falls upon the specimen, countless numbers of bacteria should be seen moving about in the preparation. It may be possible to distinguish the various shapes. The student should try to do this. Write up the experiment in the form of a

report, telling what you have done and what you have seen. Give your impression of the size, shape, and so on, of the bacteria.

ALGÆ

There are numerous kinds of algæ (Fig. 36), some very large and some very small. They are classified into such groups as blue-greens, yellow-greens, browns, and reds. The blue-greens are small and not so often studied; the greens, as *Spirogyra*, the familiar pond scum of late summer, are common; the browns are in general a coarse form found in the ocean. These forms frequently attain great lengths, as much as 700 feet or more, which would make them our longest plants. The reds are a more delicate form, found in the ocean usually at greater depths. We cannot study all of these, but good articles discussing them may be read as outside assignments. We will study one form of the green algæ as a representative of this group. It is *Spirogyra*, the familiar form mentioned above, which is easily obtainable.

FIG. 36. Protococcus, a green alga

Exercise 90. A Study of *Spirogyra*

Materials needed. *Spirogyra*; compound microscope; slide; cover glass; needles.

1. Obtain a very small piece of *Spirogyra*, not larger than a fourth the size of a garden pea, and mount it on a slide (Fig. 37). With two needles gently tease the threads apart until they are well separated. Doing this roughly will destroy the delicate specimen. If there is not enough water on the specimen, supply a drop. Cover with a cover glass. Study under the low power of the compound microscope.

a. Do you see the filaments?
b. Describe them as to length, shape, and size.
c. Do they contain a spiral band, the chloroplast?
d. Is there one or more than one of these chloroplasts?
e. What is the color of a chloroplast in *Spirogyra*?
f. Is the rest of the cell colored?
g. Where do you think the food is manufactured?
h. Is the filament made up of one or of several cells?
i. Draw a single cell enlarged to 3 inches. Label the chloroplast, cell wall, nucleus if seen, and cytoplasm.

FIG. 37. Portion of a plant of *Spirogyra*

Observe the spiral chloroplast, the cytoplasm, and the nucleus

2. If possible, secure material of *Spirogyra* which is reproducing. In collecting *Spirogyra* you will notice that the light yellow or straw color rather than the green will be generally found to be reproducing. The student should read the discussion on *Spirogyra* in Pool and Evans's "First Course in Botany." Mount carefully upon a slide some filaments that are reproducing, following the same directions as given above. Unless care is exercised the specimen will be injured.

a. Do you find the filaments conjugating, that is, coming together in pairs? When two filaments come to lie alongside of each other, little tube-like projections are put out from adjacent cells. Those from the cells of one filament unite with those from the cells of the other filament, so that the two filaments come to form a ladder-like arrangement.

b. Do you see the ladder-like arrangement? Can you distinguish that it is formed by the projection of the cell walls?

c. The cell contents of one filament passes over into the other filament and fuses with it. This material then forms a dense, dark body, the reproductive body. Do you see the reproductive bodies?

d. Are there many of them? These reproductive bodies sink to the bottom of the pond and remain over winter. In the spring, growth begins and they float to the surface, where reproduction again occurs.

e. Draw two filaments conjugating, showing all parts. Label cells, tubes between cells, and reproductive bodies. If possible, show stages in the process of the chloroplast moving from one cell into the other.

f. Do the chloroplasts always move in one direction only?

YEASTS

Exercise 91. A Study of the Yeast Plant

The yeasts are organisms common in the air as wild forms. They can be secured from the air and cultivated. In former times wild yeast for making bread was secured from the air. This was done by exposing a culture solution containing sugar to the air. Yeast plants dropped into it and the reaction started. Now it is customary to buy compressed yeast and put it directly into the culture solution.

Materials needed. Cake of fresh yeast; small culture dish.

1. Mix the yeast with a few tablespoonfuls of water. Allow it to stand for a few hours or overnight in a warm place. Study a drop of the liquid under high power. The yeast is mixed with corn meal or some similar ingredient to form cakes. When this settles, the yeast plants will be found in the liquid.

a. Do you find yeast plants present in the liquid?

b. Are they abundant?

c. What is their shape?

d. Do they occur singly, in groups, or in chains?

2. Yeast reproduces by budding. A single large plant gives rise to a small bud which continues to grow. This new cell buds again and again, forming a chain of several plants. The chain is readily broken up by rough handling.

a. Do you find budding plants?
b. How many buds do you find?
c. Can you tell which was the original plant?
d. Draw several plants, showing buds in various stages. Enlarge the original cell to the size of a dime and the others in proportion.

3. Yeast grows rapidly when present in a sugar solution such as is prepared for bread-making. When the plant has been allowed to grow for a time, it changes the sugar to carbon dioxide and alcohol. The carbon dioxide rises from the solution as a gas; the alcohol remains in the solution.

After the yeast has been standing in a warm place for about twelve hours, it is mixed with the flour to form dough.

a. Do you think the yeast continues to grow in the bread dough?
b. What becomes of the carbon dioxide?
c. Why does the bread rise?

4. Wheat flour contains gluten, a substance which is somewhat elastic. The accumulation of carbon dioxide in the dough causes it to rise. Kneading the dough drives off the carbon dioxide, and the mixture will rise again after the yeast has worked. Alcohol is also formed in the bread dough.

a. Is the alcohol in the dough? How do you know?
b. Does it pass off with kneading?
c. What becomes of it?

5. When bread is put into the oven and heated, the carbon dioxide expands and so the loaves puff up. When baked, the gluten loses its elasticity and the carbon dioxide escapes. The alcohol is very volatile and it too is driven off through the meshwork of openings left by the carbon

dioxide. Thus what was unwholesome dough becomes very palatable bread.

a. Do you think yeast plants are important?
b. Why does bread sometimes fail to rise?
c. Do you think yeast would grow where it is cold?
d. Sometimes the housewife says that the yeast has been chilled. What is the effect?
e. Will chilled yeast make good bread?
f. What is the value of the carbon dioxide in the dough?
g. Is the alcohol of any value?
h. What becomes of it upon baking the bread?

THE MOLDS

Exercise 92. A Study of the Bread Mold

Materials needed. Slice of bread; culture dish; compound microscope; slide; cover glass.

1. The spores of bread mold are abundant in the air at all times. Moisten a piece of bread and place it in a glass dish with a cover. Place it in a warm place for two or three days. By this time spores which were present on the bread will have developed into a cottony mass which is the *mycelium* of bread mold. A single thread of this mycelium is called a *hypha* (plural, *hyphæ*). With further development the mold forms spore-cases on the tops of certain erect hyphæ. These spore-cases, called *sporangia*, contain black spores which reproduce the plant. Spores similar to these produced the mold plants you are studying.

a. Can you see the mycelium?
b. Describe it as it appears to you.
c. Do you distinguish individual hyphæ?
d. What color are they?
e. Do you note certain hyphæ that extend between plants? These are called *stolons* and give rise to new plants.
f. Draw a single plant enlarged, showing hyphæ, stolons, sporangium, and mycelium.

g. Mount a few spores in a little water in the usual manner and draw under the high power of the compound microscope.
h. Had you ever seen bread mold before?
i. Where does it grow best, in a hot or cold, moist or dry situation?
j. Why is a bread box an ideal place for mold to grow?
k. When is it best suited for molds?

2. Write a report on molds, telling all the essential features which you have ascertained. Read a written account of this fungus in some good text or reference book. Any encyclopedia will give you the necessary material.

Exercise 93. A Study of the Mushroom

Materials needed. Mushrooms; compound microscope; slide; cover glass.

1. Many people believe there is a difference between the mushroom and the toadstool, — that one is harmless and the other poisonous, — but this is an error. There are, of course, poisonous varieties; but all these fungi may be designated by either name, although there is a growing tendency to drop the name "toadstool" and designate them all as mushrooms. These are *saprophytes*, which live on decaying organic materials such as rotting wood and vegetable decay. There is usually much more of the fungus unseen in the substratum than in the small, umbrella-like part that appears aboveground. This umbrella-like part is the fruiting body which bears the reproductive cells. It only appears aboveground when the plant is reproducing. If a small portion of this is examined under the high power of a compound microscope, it will be found to be made up of a mass of hyphæ bound closely together. Mushrooms can usually be found around old stumps, on the trunks and branches of decaying trees, and in other places where much organic matter is decomposing.

a. Draw the fruiting portion of a mushroom. It should be about 3 inches high.

b. The stalk is called the *stipe*; the top is called the *cap*. Label these parts.

c. Split the specimen in halves perpendicularly. Draw a view of the cut surface. The *gills* may be seen within the cap. Label all parts.

d. The gills bear the *spores* which reproduce the fungus. The spores may be seen by mounting a piece of the lower edge of one of the gills and examining with a compound microscope. Do you see the spores? Draw a spore enlarged.

2. Write a report, giving the main points in the life history of a mushroom and other facts of interest concerning its growth.

3. Read a good reference on "fairy rings" and write a paper on the subject.

MOSSES

Exercise 94. A Study of the Moss Plant

The mosses are tiny plants not over a few inches tall. Early in the season the small leafy plant may be found in damp shady places. It is often found on the north side of trees near their base where it is moist.

Later in the season a slender stalk about as thick as a needle grows out from the top of the green plant. It is generally not over an inch or two in length and bears a capsule at its upper end. In this capsule are borne the spores. These spores fall to the ground, and the following season each grows out into a little thread called *protonema*. From the end of a protonema the leafy moss plant develops.

If one examines carefully the top of a leafy moss plant, he may find rosettes of leaves clumped closely together. In some of these are found flask-like organs, the *archegonia*, which contain within them a single egg. In other heads are

found peculiar club-shaped organs, the *antheridia*, which contain sperms. When mature the sperms travel over into the flask-like archegonium and fertilize the egg. It is the fertilized egg that develops into the stalk-like organ with the capsule which was mentioned above.

Materials needed. Moss plants; compound microscope; slide; cover glass.

1. Secure specimens of mosses and let each student draw and describe a moss plant as explained above. He should be sure that he understands the life history, which is simply explained here.

Label all the parts seen. A spore from the capsule should be mounted in the usual manner in water and drawn. Draw the life history in the form of a diagram.

FERNS

Exercise 95. A Study of the Fern Plant

Materials needed. Fern fronds; compound microscope; hand lens; slide; cover glass.

1. The fern plant is familiar to everyone. It is one of our most beautiful plants and is much used for decorative purposes.

a. Draw a leaf of a fern. This is called a *frond.* Note that it is divided into numerous small leaflets.

b. Do you find the brown "fruit dots," or *sori,* on the back of the leaflets? If not, secure a specimen from the teacher.

c. Are the sori arranged in any order? Explain the system.

d. Are the sori circular in outline or some other shape?

e. Draw an enlarged leaflet of the fern, showing how the sori are distributed.

f. Examine a fruit dot with a hand lens (Fig. 38). Do you see a shield over each sorus? What shape is it?

g. Draw a sorus showing this shield, which is called the *indusium.*

2. Remove part of a sorus and mount it in the usual manner. You will find it is made up of numerous small stalked bodies, the *sporangia*. A single sporangium is about the shape of a watch, much flattened, and has a row of thick cells along the edge. These thickened cells are called the *annulus*. When the sporangium dries, the annulus contracts unevenly and the sporangium is ruptured forcibly, thus scattering the spores.

a. Draw a sporangium enlarged to the size of a 50-cent piece. Show the annulus. Note carefully that its outer wall is thin, whereas the inside walls are thick.

b. Remove the cover glass and allow the preparation to dry. Watch the sporangia through the microscope. If you are patient, you will see the annulus spring forcibly back and forth, scattering the spores. Explain in writing what you have observed.

c. Draw a ruptured sporangium.

3. The spores from the sporangia grow into a small green body about an eighth of an inch square, called the *prothallium*. The prothallium produces *sperms* in *antheridia*, and *eggs* in *archegonia*. When fertilization takes place, a new fern plant develops.

a. Write a short sketch of the life history of a fern plant, telling any interesting facts which you have learned either from observation or from discussion and reading.

LIFE HISTORY OF A SEED PLANT

The seed plants produce true flowers. It is through the presence of flowers that seeds are formed. This great group gets its name from the fact that it bears seeds. The flower produces stamens, which form pollen, and an ovary, which produces seeds, or ovules, containing the eggs.

Each pollen grain gives rise to two nuclei, the sperms, which fertilize the egg and thus form an embryo. Since the egg is within a seed, the young embryo is embedded

FIG. 38. A fern (*Aspidium*)

a, fern frond; *b*, section of fruit dot (sorus); *c*, unripe fruit dots; *d*, ripe fruit dots

therein when it is formed. The dispersal of the seed and its germination results in a new plant.

Exercise 96. A Study of the Life History of a Lily

Materials needed. Lily flowers; compound microscope; slide; cover glass; sugar.

1. Secure a stamen from a lily and study it carefully.

   a. Draw the stamen enlarged to one inch. Label filament and anther.
   b. Note how the anther ruptures and releases the pollen.
   c. Draw a few pollen grains as seen under a compound microscope. If prepared slides of pollen are used, note the nuclei present. How many nuclei are there?
   d. If desired, the pollen grains may be placed in a 5-per-cent solution of sugar and allowed to germinate. It should not require over a few hours for germination with formation of the pollen tube.
   e. Draw a pollen grain which is germinating. Show the pollen tube and the tube nucleus. If the two sperms are present and seen, label them.

2. If prepared slides of lily ovaries are available, study them and become familiar with their structure.

   a. Draw an ovule, showing how it is attached. To what are ovules attached?
   b. What type of placenta is this? Is the micropyle present?
   c. What is the stalk that attaches the ovule called?
   d. Do you see protective layers about the ovule?
   e. Label all parts, such as micropyle, integuments, embryo sac, funiculus, ovule, and placenta.
   f. Draw an embryo sac in detail. How many nuclei are in it?
   g. How do you distinguish the egg nucleus? the endosperm nucleus? One sperm unites with the egg, the other with the endosperm nucleus. This is called *fertilization.*
   h. What is produced by the fertilized egg?
   i. What is produced by the fertilized endosperm nucleus?
   j. What is a ripened ovule? How does it produce a new plant?

PLANT-BREEDING

The science of plant-breeding, also called *genetics*, is of great importance in the improvement of plants and animals. There are few species which do not show the beneficial results of plant-breeding. Improvement may be slow or rapid according to the methods used. There are few farmers, indeed, who do not practice selection in crops, and none who do not believe in the value of pure-bred sires even though they are not always used.

Exercise 97. A Study of Field-Selected versus Crib-Selected Corn

Nearly all up-to-date farmers select their corn from the stalks as they stand in the field early in the fall. Such a procedure has two outstanding advantages: first, the parent which bore the ear can be seen and inspected for outstanding characteristics; and second, the selection at an early date before the first frost insures against damage to the ear before it has dried. If the ear is still full of sap, frost is likely to lower the germination. To select ears at random from a crib is equivalent to selecting a sire from a herd composed of pure-bred and grade animals, the pedigree of none being known. There is as great a possibility of failure as there is of success.

Materials needed. Field-selected seed corn; cribbed corn; rag-doll tester.

Determine from the students or others where field-selected seed may be seen. It is undoubtedly possible to study cribbed corn at the same place unless the study is carried on at the wrong season.

a. From what type of stalk should a seed ear be selected?
b. Should it be large or small?
c. Does it matter whether or not it is vigorous?
d. What would denote vigor to you in a cornstalk?
e. At what node is the ear usually found? Count a dozen or more stalks.
f. At what angle should an ear selected for seed be borne?
g. Explain points in favor of this and against other angles (Fig. 39).
h. Should a stalk bearing a good seed ear be green or dead?
i. Would a normal stalk be dead before the ear which it was maturing?
j. Do you think it would be natural for the stalk to die first? Why?
k. What might cause such an occurrence?
l. Is it good judgment to select an immature ear from a dead stalk?
m. Explain your answer, giving the reasons in support of it.
n. Do you believe it would be better policy to select mature ears from green stalks? Explain your position.

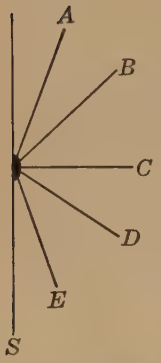

FIG. 39. Position of ear

The ear may assume position *A*, *B*, *C*, *D*, or *E*; *S*, the stalk. Positions *A*, *B*, *C*, are the most desirable

Very often stalks break or lean over. Many times after windstorms early in the fall much corn is found broken or bent at one of the nodes. Other stalks lean badly. If the soil is softened by rain, a wind may readily blow stalks into a leaning position.

a. Should such stalks straighten up? (Fig. 40.)
b. Why do some stalks become erect again and some do not?
c. Do you think ears may be of influence?
d. Do you think it would be wise to select ears for seed from stalks which are permanently down?
e. Do you think seed ears of good quality may be selected from broken stalks?
f. What may cause stalks to break at the nodes?

g. Do you think that ears in the *E* position, with broken shanks, should be selected as seed?

h. Are such ears likely to be diseased?

i. Might disease in the shank weaken it enough so that it would break?

Let each student select ears from various types of stalks (Fig. 41). Select a mature ear from a green stalk, an immature ear from a prematurely dead stalk, an ear from a leaning stalk, an ear from a broken stalk, and an ear with a broken shank hanging in the *E* position. These ears may be marked with a piece of paper on a shingle nail thrust into the pith at the butt end of the cob. In the laboratory germinate 25 grains from each ear. The "ragdoll" method of testing may be used (Fig. 42, on page 138). (See Pool and Evans's "First Course in Botany.")

Record the percentage of germination for each

FIG. 40. The effect of weak and strong root systems in corn

These two stalks blew down during a rainstorm. The stalk at the left, which bears two ears, straightened up later; the stalk at the right without an ear did not. The pit about the stalks shows operations preparatory to working out the root systems

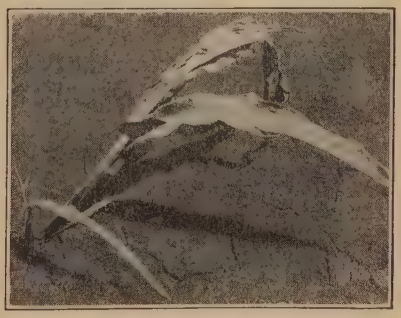

FIG. 41. A stalk of corn the progeny of an ear from a down stalk

After a fair start this stalk is dying, owing to a poor root system

type and draw conclusions as to the selection of seed in the field. The class averages on these germinations should be considered. If the corn selected for the above is still immature, it would be well to dry it for a few weeks and then return to complete the experiment.

Select 100 kernels at random from corn which has been picked as seed from the field by some farmer. At the same time select 100 kernels from crib-selected seed. If the latter

FIG. 42. A rag-doll tester unrolled, showing the germination test
Each row is from the corresponding ear above it. (Courtesy of the Indiana Agricultural Experiment Station)

is not available, select the kernels directly from good ears in the crib (Fig. 43). Germinate the two lots simultaneously in the same tester.

a. Is there a difference in germination at the end of a week?
b. If so, in favor of which lot?
c. Does it appear that one method has an advantage over the other?
d. What would you advise if you were asked for an opinion?

Write an essay on seed-corn selection entitled, "Field Selection versus Crib Selection of Seed Corn." Use your own words, but make use of any material with which you are familiar (Figs. 44 and 45). Your experiment station may have bulletins which will be available.

FIG. 43. Weighing and computing field tests on corn

FIG. 44. A row of corn grown from an ear which was determined as of good quality on the germinator

Compare with Fig. 45

Exercise 98. **A Study of Mendel's Law and how it Works**

You should read the discussion in Pool and Evans's "First Course in Botany." Here among other things it is stated that Mendel found tall peas (*TT*) produced pollen grains and ovules which contained only gametes with *T* characters, whereas dwarf peas (*tt*) produced gametes with only

FIG. 45. A row of corn with only one standing stalk

This row was developed from an ear which gave a poor germinator test. (See Fig. 44)

t characters. When these unite the new individual formed is of the composition *Tt*, which is tall. Such an individual would produce both kinds of gametes, that is, *T* and *t* gametes. Peas naturally self-fertilize, therefore the coming together of pollen grains and ovules each containing *T* and *t* characters would result in a ratio of three tall peas to one short one, or four individuals, as *TT*, *Tt*, *Tt*, *tt*. The first three are tall; the last, dwarf. The question of this ratio is easily worked out.

Materials needed. Black and white marbles or white and yellow corn, 100 of each color.

1. Secure 100 white and 100 black marbles or, if these are not readily available, 100 yellow and 100 white kernels of corn, beans, or other convenient material. The material used must be uniform in size. Mix the 100 white and 100 black marbles in a box.

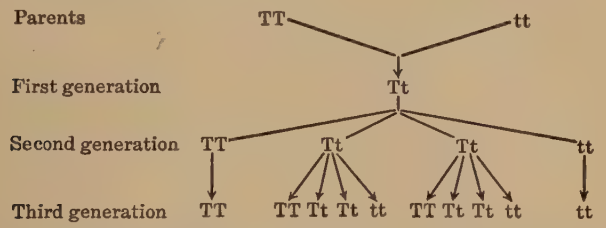

FIG. 46. A diagram showing how Mendel's Law works out upon crossing tall (TT) and dwarf (tt) plants

The first generation is tall but are Tt in make-up. Upon self-fertilization Tt gives rise to a 3 : 1 ratio of 3 tall to one dwarf individual. Two of the tall plants are Tt individuals, and, when allowed to reproduce by self-fertilization, always give a 3 : 1 ratio. The TT and tt individuals breed true and produce only progeny like themselves

Now let each student in turn draw two marbles at a time from the box. Record each draw in columns labeled *TT*, *Tt*, *tt*, where *TT* equals two blacks, *tt* equals two whites, and *Tt* equals a black and a white. Use at least 100 draws.

The number of *TT* and *tt* should be approximately equal, with the *Tt* twice as many as either of the others.

Add all those having a black marble together, that is, the columns headed *TT* and *Tt*. The ratio of the sum of these to the white should be 3 : 1.

a. Do you find this to be true?

b. In the random mating of *Tt* pollen grains with *Tt* ovules the ratio will be the same as the draws from the box. Can you see how this is true?

PLANT DISEASES

Most plant diseases are very complicated and require special equipment to study them. In studying them it should be recalled that plant diseases are caused by microscopic plants. In nearly all cases the larger plants, or the hosts, are being attacked by smaller plants, the parasites. In order to see all parts completely, one should have cross sections and use the microscope. There are certain stages which show well enough for study in many cases. Since most schools are not equipped with good cross sections for study, the laboratory work here outlined is largely of an observational type. Where cross sections and microscopes are available, the teacher should formulate directions for such sections as it seems advisable to use.

Exercise 99. A Study of Rust

Rust occurs on all cereal grains in one form or another. It is one of our most destructive diseases. In the summer the rust can be seen as the red spores on the stems and leaves of the grain. Later in the season black spores are produced instead of red ones. Rust is often referred to as red rust. Again it is called black rust. Let us remember that red and black spores are only two different stages of the same parasite. The black spores are thick-walled and live over winter. The red spores are thin-walled and are thought to be incapable of living through the winter. In the spring the black spores grow and produce a small spore called a *basidiospore*, which produces on barberry bushes a stage of the rust called the *cluster cup*. In the cluster cup is produced another type of spore called the

cluster-cup spore, which is able to infect the grain at once. After growth on the grain the red rust stage is produced.

Materials needed. Rusted grain; compound microscope; slide; cover glass; hand lens.

1. Secure some grain infected with rust. This should be collected in the summer. In the fall the class may be taken into the field and shown black rust on the old stubbles. If young grain is appearing among the old stubbles, red rust may be found upon it. A group of spores together are known as a *pustule* or a *sorus*. Examine with a hand lens.

a. Can you see that the epidermis is ruptured?
b. Is a pustule round or long?
c. How does its length and width compare?
d. Rub some red spores on your hand. Can you see them with a hand lens?
e. Is the same true of the black spores?

2. Examine a barberry bush which harbors the cluster-cup stage of wheat rust. If you do not have barberries in your community, or cluster-cups are absent on the leaves, the Conference for Prevention of Grain Rust, Minneapolis, Minnesota, will send you samples free of charge for class purposes. Various stages of the cluster-cup will be found on such material.

a. Do you see the cluster cups?
b. Are there few or many on a leaf?
c. Examine the cluster cup with the hand lens or low power of the compound microscope. Describe it.
d. Draw a barberry leaf with its cluster cups, enlarged to twice its natural size.

3. Secure a piece of grain stem with rust pustules upon it.

a. Draw a portion of the stem, showing several pustules.
b. Draw a single pustule as seen under a lens, showing detail.
c. Scrape a few red-rust spores upon a slide, mount in water, and cover with a cover glass. Examine with the high power of a compound microscope.
d. Are they rough or smooth?

e. How many cells does a red-rust spore have?

f. Is it thin-walled or thick-walled?

g. Draw a single red-rust spore enlarged to two inches. Label stalk, spore, and cell wall.

h. Among the red-rust spores you are almost sure to find black spores. They are two-celled. Are they rough or smooth walled?

i. Are they thin-walled or thick-walled as compared with the red spores?

j. Draw a single black-rust spore enlarged to two inches. Label cell wall, stalk, and cells.

k. Can rust be prevented?

l. Write an essay on rust, telling the important features in the life history and something about its importance. Refer to the latest Yearbook of the United States Department of Agriculture for material. If your school does not have a copy, the congressman from your district will be glad to send it to you. Read about rust in one of the encyclopedias referred to in the reference list.

Exercise 100. A Study of the Smuts

The smuts are destructive parasites of all cereal grains. They are found on corn, wheat, oats, rye, and barley. On corn the smut forms large masses, which are at first white, but which later turn black, producing countless numbers of spores. The smut of corn attacks any part of the plant. The smut masses may be produced on every part, but more often they are found on the nodes, leaves, and ears. The black spores produced in the autumn remain in the ground until spring, when they grow and produce another set of spores, called *air conidia,* which attack the corn plant. These air conidia may enter the plant through injuries or through tender growing points such as the buds. Since the buds are found in the axils of the leaves, the corn plant shows smut frequently upon the nodes.

Materials needed. Corn plants with smut attached; smutted wheat; slide; cover glass.

1. Study a corn plant which is smutted.

a. Where does the smut occur?
b. How large are the smut masses?
c. Which part or parts of the plant are being attacked?
d. Observe how the smut mass is attached to the stalk. Does it grow out of it?
e. Split the stalk and the smut mass in such a manner that you will be able to observe how it grows out of the stalk. Describe this as you are able to determine it. Draw it.
f. Mount some of the black spores and study them under the microscope. What shape are they?
g. Draw a portion of the stalk with a smut mass attached. The drawing should be three inches across.
h. Draw a spore enlarged to one inch.

2. Write an essay on corn smut, telling how much damage it does and something of its general importance and life history. There is no treatment effective against corn smut.

Refer to the Yearbook of the United States Department of Agriculture and the encyclopedia for material.

3. Study a specimen of covered smut from wheat or some other cereal grain. This smut occurs within the glumes of the head and is hard to discover in a field. It should be collected early in the summer while the grain is still in the field.

a. Compare a smutted head of wheat with one which is not smutted. Can you distinguish between them?
b. If the wheat is bearded, is there a difference in the angle of the beard? Explain.
c. Are the heads of smutted wheat more plump than the non-smutted heads?
d. Would this account for the angle of the beards?
e. Draw a smutted head about natural size.
f. Draw a normal head of wheat. Label rachis, beard, glumes, spikelets, and spike.

4. Carefully remove a smutted kernel from the head. Compare it with a normal kernel.

a. Do you note any difference?
b. Draw each kernel accurately enlarged to one inch.
c. Crush the smutted kernel. Does it have an odor? This odor is ordinarily described as that of spoiling fish.
d. What is the black material?
e. Mount a small portion of it in water upon a slide. Cover with a cover glass and examine under the low power of a compound microscope. Do you think they are spores?
f. What shape are they?
g. Draw several enlarged.

5. These spores when threshed are scattered over the good wheat and remain on it over winter. When the seed is planted in the spring, the waiting smut spores grow into the young wheat plant, and the smut plant growing through the stem reaches the head, where it causes damage.

a. Can covered smut of wheat be prevented?
b. How can it be done? If you are not familiar with this, read the discussion in Chapter XVIII of Pool and Evans's "First Course in Botany." If the grain is treated with formaldehyde (one pint to forty gallons of water), the smut will be destroyed. Treatment with copper carbonate dust is becoming popular. Two ounces of copper carbonate dust mixed with a bushel of wheat readily prevents covered smut.

Exercise 101. A Study of Loose Smut

Covered smut of cereals attacks only the kernel. Loose smut of grains not only destroys the kernel but also the glumes as well, so that when the spores are dispersed the blackened rachis is all that remains of the head. Loose smut of oats and rye is readily controlled by the formaldehyde treatment but not with copper carbonate.

Materials needed. Heads of cereal grains attacked by loose smut; compound microscope; slide; cover glass.

1. Secure a stalk of some cereal grain attacked by loose smut.

a. Are the glumes being attacked?
b. Examine heads which have been attacked and the spores already dispersed. What is left?
c. What color is the rachis?
d. To what is this due?
e. Mount a few spores and study in the usual manner. What shape are they?
f. Draw a head of loose smut before the spores are dispersed.
g. Draw a head after the spores have scattered.
h. Draw a single spore enlarged.

DISEASES OF POTATOES

Potatoes are one of our chief food crops and therefore need attention looking to the prevention of diseases (Fig. 47). There are numerous serious potato diseases in the United States. Among these are late blight, scab, and rhizoctonia (sometimes called black scurf). Not only does the up-to-date farmer treat the seed before planting, but he also sprays the vines later to prevent vine diseases.

Exercise 102. A Study of Scab of Potato Tubers

Scab of potato tubers not only causes a loss in the crops but also lowers the market value. This means a loss to the farmers of millions of dollars. Potato scab can generally be prevented by treatment of the tubers with hot formaldehyde or with corrosive sublimate. For full directions for such treatment, write to the director of your experiment station.

Materials needed. Potato tubers with scab upon them.

1. Secure some potatoes with scab present for examination. It may appear as deep pitting on the surface of the tuber or as thick corky areas. The tubers, which are pitted with scab, were infected early in the growing season; those

with thick corky areas on the surface represent tubers which were infected with scab late in the growing season.

a. Do you find scab on the tubers?
b. Is it the early or late type of infection?
c. Is it abundant?

2. Cut through one of the scab areas and examine the cut surface.

a. Is it deep or shallow?
b. Describe it fully. Deep pitting due to scab is usually found to be free from the scab organism. Where the scab is corky in appearance it usually has active scab organisms present. Treatment is always advised. Soils high in nitrogen are more favorable to potato scab than those low in this element.
c. Draw a cross section of a pitted scab area on a potato.
d. Draw a cross section of a tuber with the scab as corky areas.
e. Draw a tuber, showing the scab distribution on one side.

Exercise 103. A Study of Rhizoctonia, or Black Scurf, on Potato Tubers

1. This disease is widely known as rhizoctonia. It appears much as soil particles adhering to the surface of the tuber.

a. Brush the tuber. Does it brush off readily?
b. Wash the tuber in a stream of water. Soil usually washes away easily. Does rhizoctonia wash from the tuber readily?
c. What color were the spots of this disease while dry?
d. Do they change in color on being wet?
e. What is their appearance after being wet?
f. Draw a tuber, showing the spots of rhizoctonia upon it.

2. The same treatment that controls scab will also control rhizoctonia. If it is possible to plant a plot of tubers with rhizoctonia, one half treated and the other half untreated, it should be done. The difference in yield will be noticeable. The same plan may be followed for scab.

3. The spraying of potato vines with a 5–5–50 solution of Bordeaux mixture for the control of early and late blight and other diseases is worth while. Since such work must be done in the summer, it is seldom possible to demonstrate to a class. It may be studied in class from bulletins secured from your experiment station. If this is done, the student should

FIG. 47. An experiment on potatoes in the field
The cages are to exclude insects

be required to write an essay on the study, to be handed in as written work done outside of class. Information on this spray, its preparation and use, can be obtained from the director of your experiment station.

Exercise 104. A Study of Apple Rust

A certain rust is found as pustules on apple leaves. Another stage of this rust appears on red-cedar trees. It is easily recognized on the underside of apple leaves as spots slightly smaller than the end of a lead pencil. On the red-cedar tree this disease makes its appearance as a round gall,

usually called a cedar apple. The cedar apple is ordinarily about the size of an English walnut.

Materials needed. Rusted apple leaves; cedar apple galls.

1. In the springtime there are numerous gelatinous finger-like projections from the cedar apple. It is from these that the spores pass over to the apple trees.

a. Have you ever noted the cedar apples?
b. Examine the red cedars in the community for cedar apples. Do you find such galls? In the fall and winter they will be dry and more or less withered.
c. Describe them.
d. Draw one of the cedar apples.
e. If possible, study the apple leaf with the other stage of the rust. Make such notes as seem appropriate.
f. Draw a leaf, showing the rust.
g. There is no treatment for the disease except cutting down the cedars or planting resistant varieties of apples. Resistant varieties are Yellow Transparent, Maiden's Blush, Grimes, Stayman, and Winesap. The following are said to be more susceptible: Wealthy, Jonathan, Rome Beauty, York Imperial, Ben Davis, and Rhode Island Greening.

2. If time permits, pear blight, a bacterial disease of pomes, should be studied in the field. If this is not possible, the students may be required to make an outside study of the disease from bulletins and other sources as a report.

Pear blight is one of our most destructive diseases. It is often called fire blight, the dead leaves giving the appearance of having been scorched by fire. It was the first bacterial disease demonstrated as being able to attack plants. It attacks apples and pears equally. Some apples, such as Yellow Transparent and Jonathan, are especially susceptible. Such varieties as Winesap and Ben Davis are resistant. Among pears, Kieffer is more resistant than Bartlett.

THE USES OF PLANTS TO MAN

The uses to which plants are devoted are as numerous as the plants used. We scarcely realize how dependent we are on plants until we have reflected on the innumerable uses we make of them daily. They clothe, they feed, they house us. Were it not for plants we could not enjoy many of the pleasures of life. The fabric, the wood, and the rubber of the automobile are of plant origin. The paint which makes it beautiful is a plant product, and the coal that furnishes the energy to fashion it is of plants that lived ages ago. Man could live without animals with difficulty, but he most certainly could not live without plants; for plants alone can furnish us sugar, that important organic substance from which all other foods are derived.

Exercise 105. A Study of the Cotton Plant

The source of much cotton is the cotton plant of our South (Fig. 48). This fiber is derived from the hairs which cover the seeds with a quantity of white material which we call cotton. The cottonwood seed too is covered with cotton, but it is short and useless. Our cotton-growing states furnish this important fiber for weaving into cloth.

If cotton bolls are available, let the students examine them carefully. The study should be outlined as time permits.

If cotton bolls are not available for study, the structure of the fiber may be studied under the microscope. Is it a round or a flat fiber? Study a woolen fiber for contrast.

Outside readings should be assigned, and the student should present a written report of the subject. It should

include the acreage raised, the number of bales produced, the uses of the seeds, cottonseed oil, and so on.

Exercise 106. A Study of the Flax Plant

Study flax in much the same way as you did cotton.

The flax plant furnishes us linen and linseed oil, two of our important products. Find out how many acres of flax we raise, the number of bushels, the uses of the straw, where linen is made, and other items of importance.

Exercise 107. A Study of the Rubber Tree

The rubber industry is one of the most important industries because of the wide use of rubber in automobile tires. Rubber trees are largely of the tropics, but they concern us vitally. Any standard encyclopedia will furnish information on the subject. The advice and direction of the teacher will need to be followed in this matter.

Exercise 108. A Study of the Lumber Industry

The lumber industry is of vast extent. Wood is used in so many industries and so universally by all people that it takes on at once a national aspect.

Reports may be given by various members of the class on the following subjects:

1. Conservation of our Forests.
2. The Value of Arbor Day.
3. The Distribution of Forests.
4. How Forests may be had for the Future.
5. Effect on Land of Removal of Forests.
6. Lumbering.
7. Paper-Making.
8. Lumber Substitutes.
9. The Present Status of our Forests.
10. Forest Fires.

FIG. 48. A view of several cotton plants, showing the bolls attached to the plants

Photograph by the United States Department of Agriculture

FIG. 49. A view of a cotton field in our South with the workers gathering the cotton

Photograph by the United States Department of Agriculture

Exercise 109. The Corn Plant

The corn plant is the most valuable cereal plant in the United States. Its use in the fattening of live stock is of great importance. It is also a valuable food for human consumption (Fig. 44).

Secure a number of articles on corn and allow each student to select a topic to his liking, or, better still, if it seems advisable, allow each student to write upon some phase of this great cereal crop. Some topics suggested are as follows:

1. Corn as Food for People.
2. Corn as a Feed for Live Stock.
3. The Acreage and Yield of Corn.
4. Corn and its Cultivation.
5. The Origin of Corn.
6. The Use of Corn in Making Sugar, Glucose, and Like Products.
7. Corn as Hominy.
8. The Diseases of Corn.
9. The Improvement of Corn.
10. Varieties of Corn.

Exercise 110. A Study of the Wheat Plant

Next to corn in importance stands wheat. As a food for peoples it outranks corn. Its history, its culture, and its importance in world markets make an interesting story. Let each student be assigned a subject to report on concerning wheat. The following subjects are suggested:

1. The Culture of Wheat.
2. Winter Wheat and Spring Wheat.
3. The Hard and Soft Wheats.
4. Common Wheat and Durum Wheat.
5. The Making of Flour.
6. The Making of Macaroni.

7. The Diseases of Wheat.
8. The Grading of Wheat.
9. The Acreage and Production of Wheat.
10. Great Wheat Areas of the United States.

Exercise 111. Other Important Plants

It is suggested that the teacher make use of the following subjects, and any others that seem appropriate, from time to time as the basis of written work required of students:

1. Potatoes and their Culture.
2. Oranges and Lemons.
3. Watermelons and Muskmelons.
4. Rice and its Uses.
5. The Sugar Industry.
6. Apples and Pears.
7. Plums, Peaches, and Cherries.
8. Vegetables of Importance.
9. Coal and its Products.
10. Turpentine and Resin Products.

Many other topics are available. If reports are given in class, each student is sure to derive benefit from it. All reports should be long enough to require some effort to collect the material. The encyclopedias mentioned in the references will be found of much value in these as well as other studies throughout this manual.

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